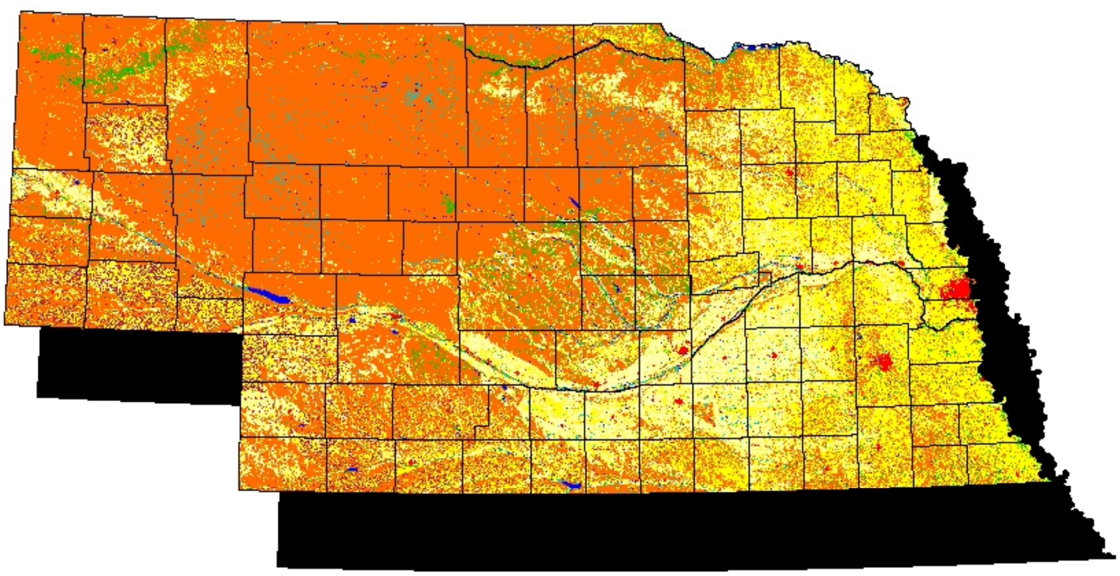
Quantifying the change in greenhouse gas emissions due to natural resource conservation practice application in NE



"The Nebraska Carbon Storage Project"

Report to the Nebraska Conservation Partnership

March, 2002

A collaborative effort between Colorado State University - Natural Resource Ecology Laboratory, the State of Nebraska, USDA Natural Resources Conservation Service and the US Department of Energy

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Project

Quantifying the change in greenhouse gas emissions due to natural resource conservation practice application in Nebraska ("The Nebraska Carbon Storage Project").

Project Authority

Nebraska state law set up a governor's task force to initiate the dialogue of C sequestration in Nebraska agriculture. Funding for the Phase I activities were made available by grants from the Nebraska Public Power District, Corn Board, Farm Policy Task Force and the Department of Energy. Funding for the Phase II activities were made available by grants from the Nebraska Environmental Trust. These grants were administered by the Nebraska Department of Natural Resources and cooperative agreements with the USDA Nebraska Natural Resources Conservation Service (NRCS). Nebraska NRCS contracted with Colorado State University Natural Resource Ecology Laboratory and USDA Natural Resources Conservation Service, Fort Collins, CO, USA to provide a state/county wide assessment of soil C in agricultural systems using the Century Eco-System Model.

Citation

Brenner, J., K. Paustian, G. Bluhm, J. Cipra, M. Easter, R. Foulk, K. Killian, R. Moore, J. Schuler, P. Smith, and S. Williams. 2002. Quantifying the change in greenhouse gas emissions due to natural resource conservation practice application in Nebraska. Colorado State University Natural Resource Ecology Laboratory and USDA Natural Resources Conservation Service, Fort Collins, CO, USA

Executive Summary

Land managers have long known the importance of soil organic matter in maintaining the productivity and sustainability of agricultural land. More recently, interest has developed in the potential for using agricultural soils to sequester C and mitigate increasing atmospheric CO_2 by adopting practices that increase standing stocks of carbon in soil organic matter and vegetation. Practices that increase the amount of CO_2 taken up by plants (through photosynthesis), which then enter the soil as plant residues, tend to increase soil C stocks. Likewise, management practices that reduce the rate of decay or "turnover" of organic matter in soils will also tend to increase carbon stocks.

In 2001, we initiated a statewide assessment of how management decisions involving cropping and tillage systems affect soil organic matter. Our approach utilized a variety of resource data (on climate, soils, land use and management), long-term field experiment results, and the Century EcoSystem Soil Organic Matter Computer Model. An initial Phase I study of cropland in Nebraska utilized existing information on climate, soils and management factors (e.g., drainage, crops grown, production levels and tillage systems) to estimate current rates of C sequestration in Nebraska and derived a value of 1.7 million metric tonnes per year (MMT). It was estimated that this annual rate of C sequestration could be maintained and increased to 2.3 MMT of C if all cropland were converted to a no tillage management system. From this Phase I study, it was apparent that the individual counties had land use information, including management histories of cropping rotations, drainage histories, fertilizer rates, and conservation practices that were not available in published databases.

The Phase II study was started in 2001 and involved all 93 counties. This general approach of involving every county within a state had recently been successfully used in similar studies in Iowa and Indiana. To communicate with the local land managers and collect the local data, the Carbon Sequestration Rural Appraisal (CSRA) survey instrument was modified, tested and implemented in each county using an electronic spreadsheet format. Individually tailored spreadsheets were prepared for each county and electronically transmitted to Nebraska. Local data only available at the county level was filled in each spreadsheet. All spreadsheets were electronically transmitted back to Fort Collins, CO when completed. This local data provided additional inputs into the Century Model that were not available in previously published databases, and refined the output for the individual counties and the soils and crop/tillage systems within each county. Century

estimates for approximately one million different scenarios showing the C changes are now available in the Nebraska CarbOn Management Evaluation Tool (COMET) database. The county summaries for the amounts of C sequestered in 1990-2000 are also available.

The Phase II assessment for Nebraska suggests that agricultural soils are currently (based on 2000 data) sequestering 1.28 MMT of carbon per year (equivalent to 4.7 MMT of CO_2 per year), largely through increased adoption of conservation practices over the past 10 to 20 years. Non irrigated systems provide 45% of the sequestration benefit on cropland while irrigated systems provide the remaining 55% of the benefit. The model predicts that rotations that include fallow periods utilizing intensive tillage practices are very close to C neutral or in some case are losing C. Grass plantings continue to sequester C, but the rates are decreasing due to the length of time that they have been in place. The application of sound conservation practices on Nebraska cropland is sequestering C and is equivalent to an offset of 12% of Nebraska's 1999 fossil fuel carbon emissions. Rangeland has the potential to sequester 5 MMT of C over the next 20 years through the application of grazing management practices on areas identified as being in fair or poor range condition.

Background

During the last century, human activities, such as burning fossil fuels, have dramatically increased the concentration of greenhouse gases (GHGs) in the atmosphere. GHGs trap heat inside the atmosphere much like the way glass traps heat inside a greenhouse (Figure 1). Without these gases, the earth would be too cold for human habitation (U.S. Global Change Research Program, 2000). However, the effects of the human-induced increase in GHG concentrations are uncertain. Many scientists believe that increased atmospheric GHGs will result in unpredictable and potentially severe changes to the Earth's climate with unknown impacts on weather patterns, sea levels, cropland production, and national economies (IPCC, 1996).

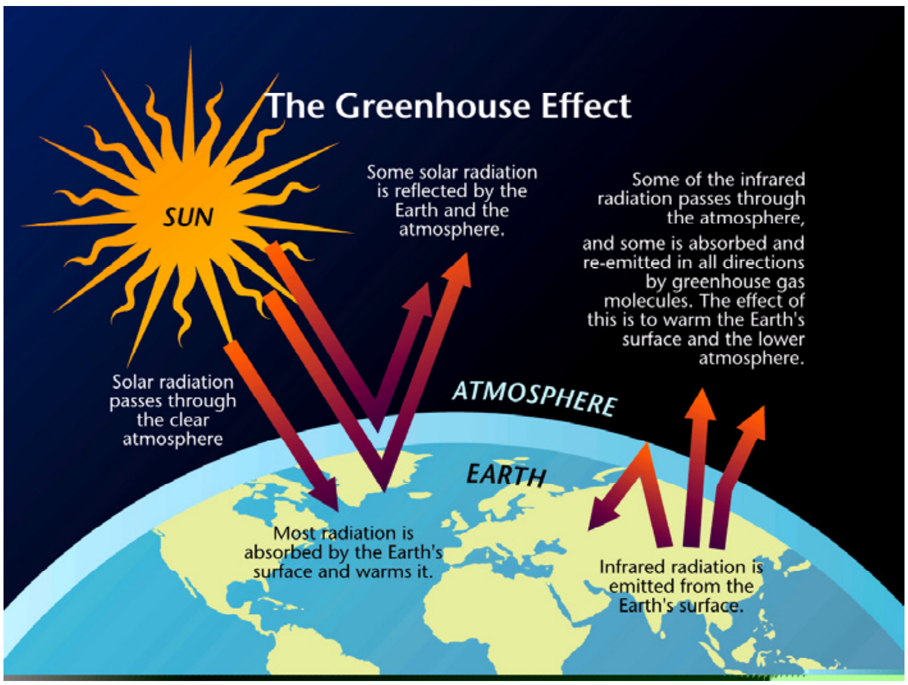


Figure 1: The greenhouse effect

GHGs are produced naturally in the environment and have resided in the atmosphere since well before the age of industrialization when humans began to contribute additional amounts to the atmosphere. Three GHGs that are of primary concern include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). This study concentrates on CO_2, which is the most prevalent GHG in terms of quantity in the atmosphere and has the greatest overall effect on warming. However, on a molecule-for-molecule basis, N_2O has the greatest warming potential, followed by CH_4 and then CO_2. Carbon dioxide levels have risen substantially over the past century as evidenced by the long-term record of ice cores and atmospheric measurements shown in Figure 2 (Neftel et al., 1994; Keeling, et al., 2000).

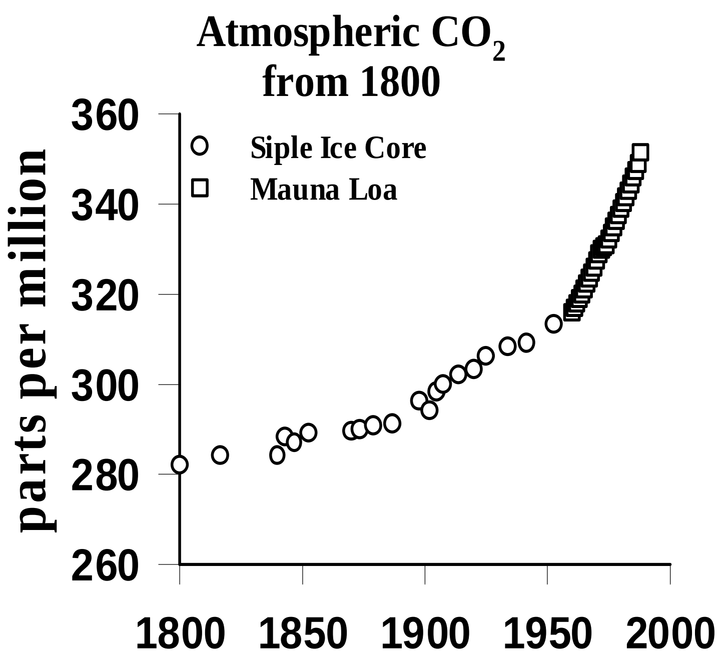


Figure 2: Atmospheric CO_2 from 1800-present

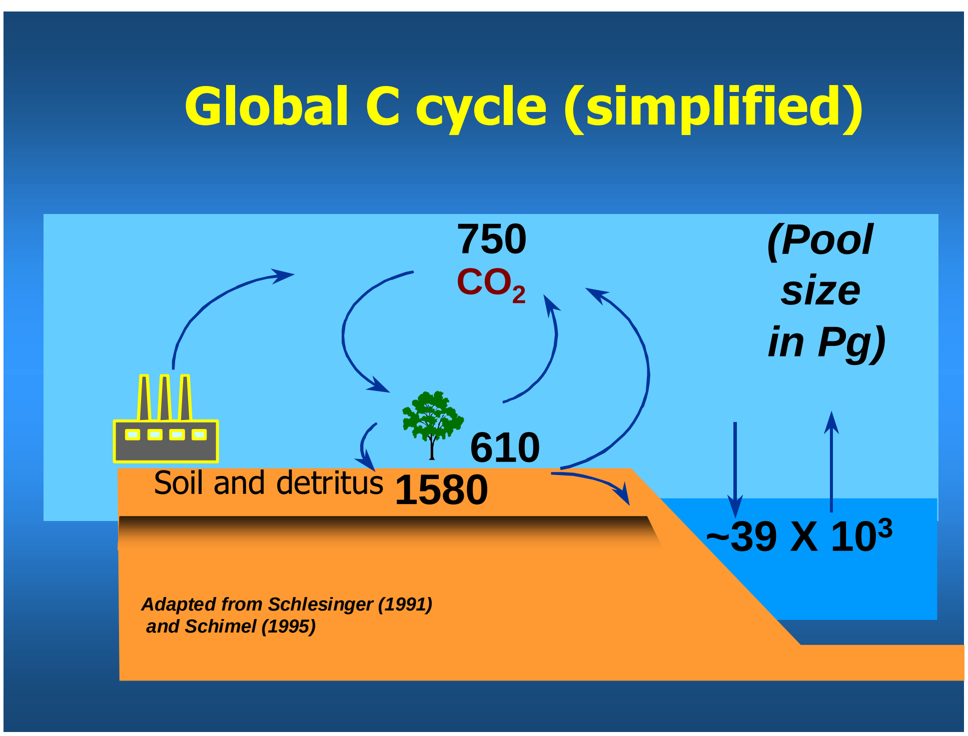


Figure 3: The global C cycle

The continual cycling of carbon through the earth's atmosphere and terrestrial biota make up an important part of the global carbon cycle (Figure 3, Schlesinger, 1991; Schimel, 1995). CO_2 is released into the atmosphere as a product of respiration, the process used by plants, animals, and microorganisms to gain energy for bodily functions. Humans, through industrial activities, have added CO_2 to the atmosphere due to the burning of fossil fuels (coal, natural gas, and oil). CO_2 is removed from the atmosphere during photosynthesis when plants convert it into biomass, including leaves, branches, stems, and roots. This biomass carbon will eventually be returned to the atmosphere upon the death and decomposition of the organism. In the interim, it is sequestered or retained on the land as dead plant and animal material that is broken down by microorganisms and incorporated into the soil. Carbon can remain in soils for thousands of years, effectively storing or sequestering CO_2 from the atmosphere (Figure 4).

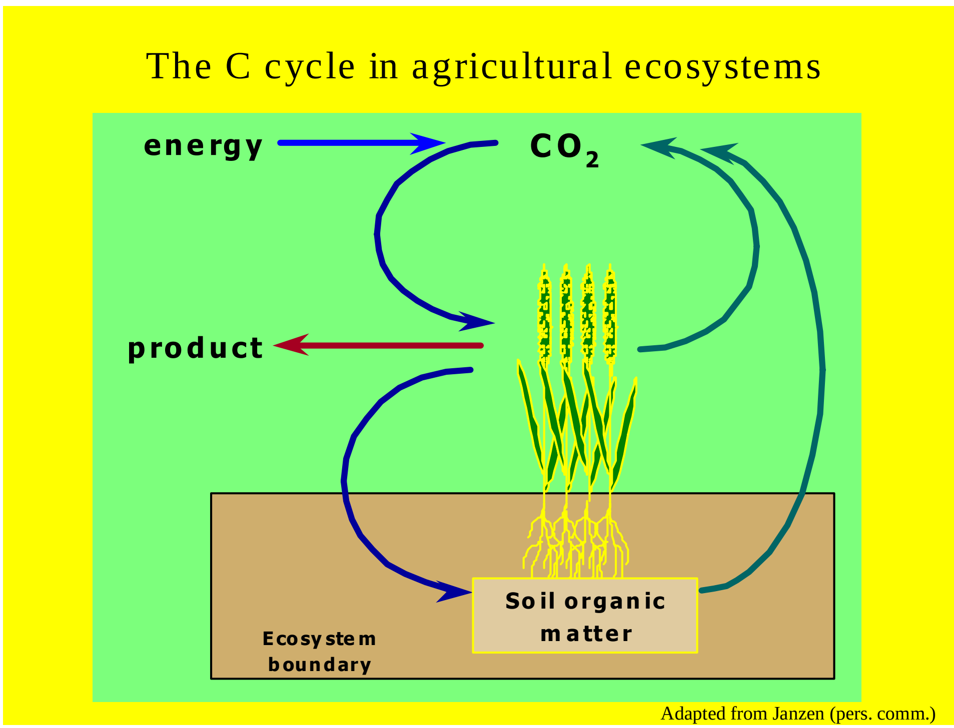
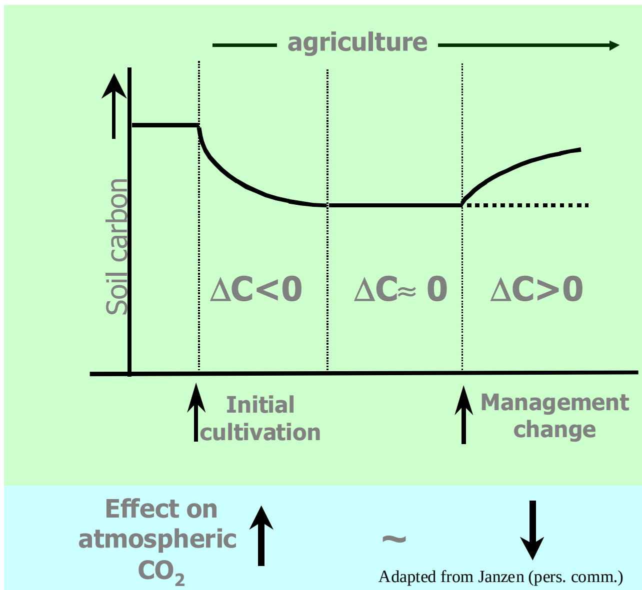


Figure 4: C cycle in agricultural ecosystems

Agricultural soils contain substantial amounts of carbon, typically 20 to 80 tonnes per hectare in the top 20 cm. However, relative to their native ecosystem levels, most agricultural soils are depleted in carbon, having lost 30-50% of their original carbon levels due to changes associated with production agriculture and past management practices (Figure 5). Historically, agricultural practices often resulted in reduced inputs of carbon through plant residues and increased losses via decomposition and erosion (Paustian et al. 1997a). Lower productivity,

Soil C trajectories



Cropped soils have been historically depleted in C, which can be regained with improved management

Figure 5: Soil C trajectories

Past Agricultural Practices

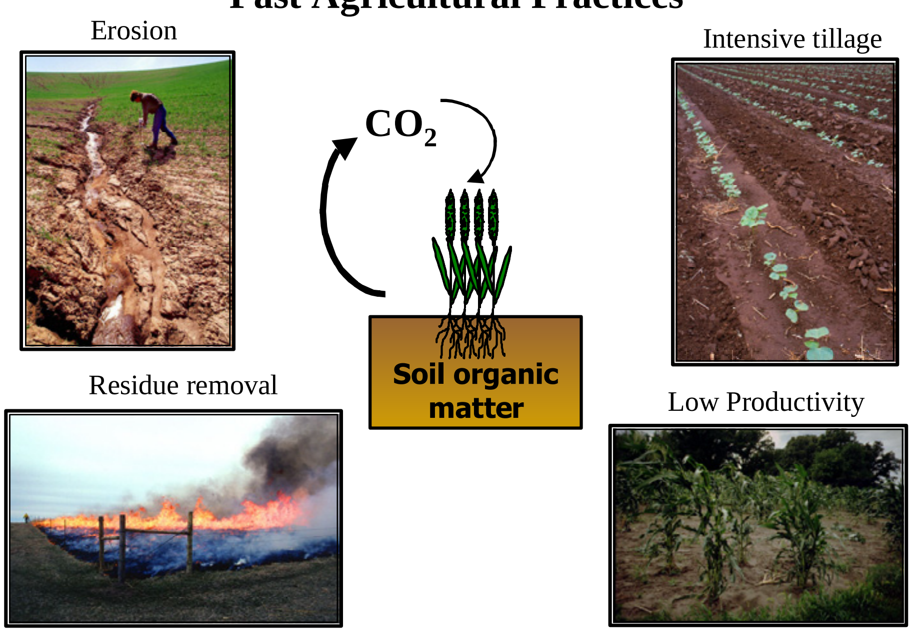


Figure 6: Past agriculture practices

particularly prior to the 1950s, and greater removal of crop residues decreased the amount of plant material that could potentially add carbon to the soil (Figure 6). More intensive tillage, allowing microorganisms to break down more organic matter and encouraging soil erosion, increased losses of soil carbon.

Through improved agricultural practices, farmers can increase carbon storage in soils (Paustian et al., 1997a, 1998, 2000; Lal et al., 1998). Conservation tillage (e.g., no-till or reduced till) helps protect soil carbon from microbial attack by preserving a more stable aggregate structure and also helps to decrease soil erosion. Better residue management enhances carbon input to soil by leaving more plant material in the fields for conversion to soil organic matter. Improved cropping rotations can also enhance soil productivity by increasing the amount of plant material that becomes soil organic matter. Winter cover crops add additional residues to the soil and help decrease soil erosion and nitrogen losses. An effective option for increasing carbon storage in the soil is to set aside land in long-term, permanent cover, such as the Conservation Reserve Program (CRP) as well as in conservation buffers (e.g. filter strips, grassed waterways). This leads to higher amounts of soil organic matter because there is reduced soil disturbance and more plant material incorporated into the soil by the perennial biomass (Figure 7).

The United States is involved, both nationally and internationally, in efforts to stabilize atmospheric GHG concentrations at a level that would prevent dangerous interference with the Earth's climate. Title XVI of the Energy Policy Act of 1992 addresses global climate change, and Section 1605(b) specifically mandates the development of procedures for the voluntary reporting of GHG emission reductions. Agriculture has shown that the voluntary application of conservation practices can provide sustainability and protection of natural resources.

Over the last 60 years, the NRCS, working through 3,000 local conservation districts and natural resource districts (NRD's) have provided technical assistance and funding to farmers who implement soil and water conservation practices. Many of these practices utilize permanent vegetation and crop residues to increase soil organic matter, which are also providing a benefit of removing CO_2 from the atmosphere and sequestering C in the soil. These management practices have been implemented according to NRCS standards and specifications, and are recorded in NRD records as verifiable documentation of their existence and location.

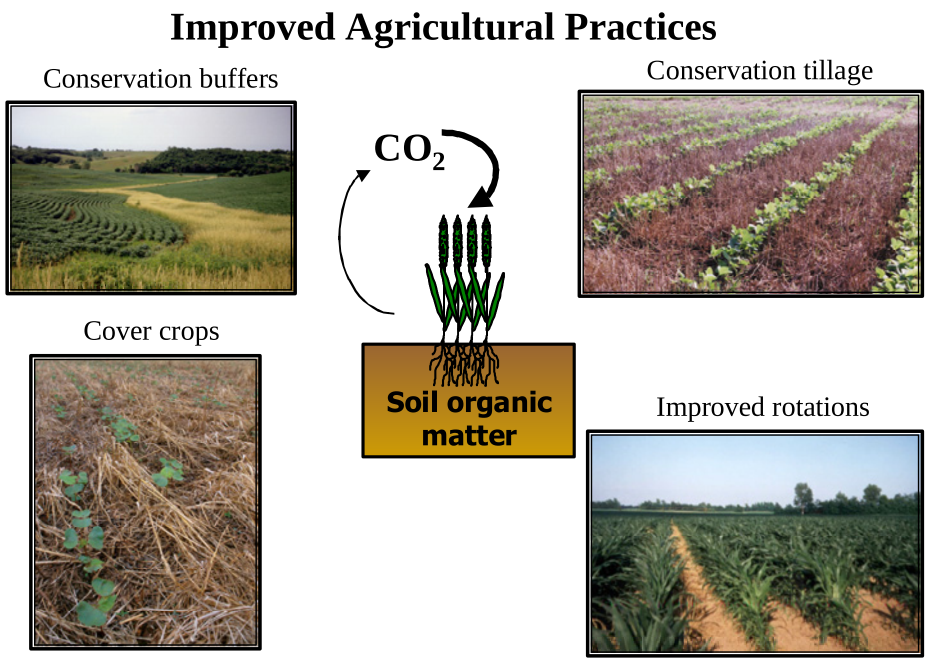


Figure 7: Improved agricultural practices

Objectives And Outcomes

The growing recognition that human-induced increases in the concentrations of greenhouse constitutes a serious environmental threat – together with the realization that agriculture can play a significant role in mitigating this threat – has stimulated interest, both in the private and the public sector, in pursuing agriculturally-based mitigation strategies. To develop and implement effective mitigation programs, quantification and assessment capabilities are needed.

Our objectives were

I) to develop Nebraska datasets detailing climate, soils, irrigation and land use needed to provide inputs into the Century model

II) to provide an assessment of current rates of carbon sequestration on a statewide basis in Nebraska,

III) to assess the potential for increased carbon sequestration with wider adoption of conservation practices and

IV) to provide locally-relevant estimates and decision tools for evaluating alternative management strategies with respect to their potential to sequester carbon in soils.

The analysis was designed to account for the complex interactions of varying climate, soil and management conditions across the State, both to increase the accuracy of the total estimates for the state as well as to provide locally-relevant information for managers and decision-makers in individual counties/NRD's. The assessment was initiated using existing information compiled by USDA/NRCS and other sources, together with a state-of-the-art simulation model capable of integrating climate and soil conditions, land use change and agricultural management practices and their effects on soil carbon changes over time. The Century model, developed by the Natural Resource Ecology Laboratory/Colorado State University and USDA/ARS, was chosen, based on its ability to incorporate effects of historical land use and a wide variety of management practices as well as its wide-spread use and recognition in the US and internationally.

Following an initial project phase utilizing existing information on land use and management practices, the project was expanded to include acquisition and use of locally derived information, through the development of a survey instrument called the Carbon Sequestration Rural Appraisal (CSRA). The objectives of the CSRA were to provide local input about current and historical management practices for use in the modeling and at the same time to provide training and information about greenhouse gas mitigation and carbon sequestration.

Products of the research include statewide estimates of carbon sequestration, broken out for various land use and management practices and displayed by maps and county-level tables to show spatial distributions across the state. The COMET (CarbOn Management Evaluation Tool) database, which can be queried by specific soils, historical land use, and management combinations for each county in the state, provides a means for local NRD's to estimate the effects of current management systems on carbon sequestration and to make projections of carbon sequestration through changes in management and the adoption of conservation practices. NRCS offices will be able to use this database to assist them in the planning process and provide assistance on best management practices as well as other local agricultural producers, policy makers and business interests. Estimates of current soil carbon sequestration for each county can be submitted to DOE as part of a program on voluntary greenhouse gas mitigation reporting. Results of the project have been presented at numerous scientific and public meetings, trade journals and newspaper articles. Results of the study will be reported in scientific publications and in upcoming conferences and workshops.

Assessment Procedure

Our approach combines data and modeling within an overall framework designed for quantifying regional ecosystem properties and dynamics (Figure 8). Here we briefly describe this framework, which is discussed in more detail in Paustian et al. (1995), Elliott and Cole (1989),and Brenner et al. (2001).

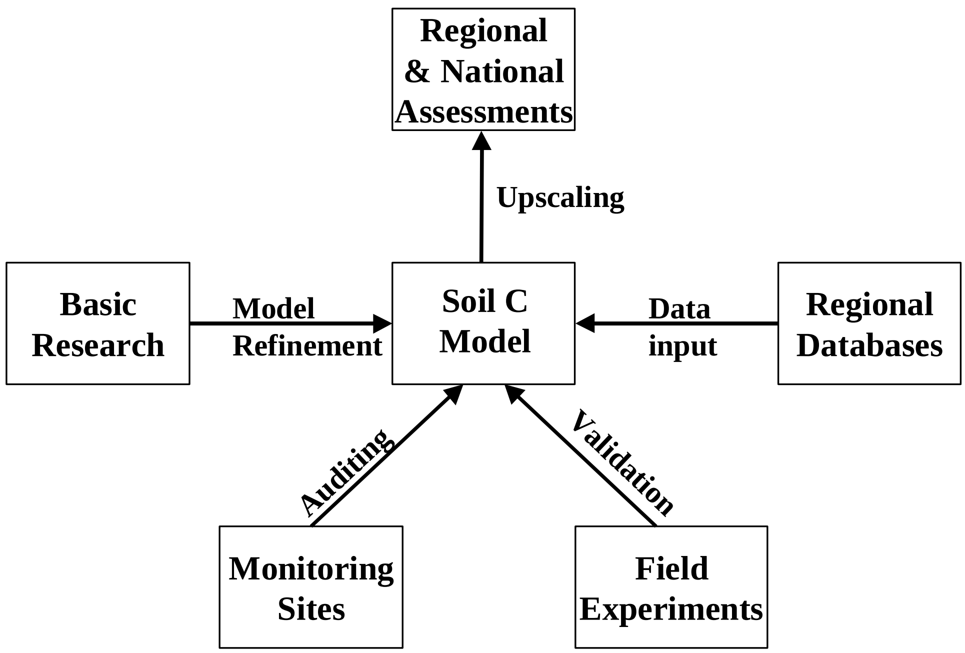


Figure 8: Framework for ecosystem modeling

The overall integration is provided by a simulation model, which is based on extensive basic research on ecosystem carbon and nutrient dynamics. The model utilizes spatial databases of driving variables (i.e. climate, soil properties, management factors) to calculate soil C changes for combinations of these driving variables, allowing the results to be combined and scaled up to the county and state levels. Data from long-term experiments, spanning a similar range of climate, soil and management, are used to test and validate model performance across the range of conditions in the region. The establishment of on-farm monitoring or 'benchmark' sites provides additional field-based verification, under actual farm conditions, of soil C changes due to management. A monitoring system, however, has not been established at this time in Nebraska and was not a component of this study.

Modeling Soil Organic Matter

The Century EcoSystem Soil Organic Matter Computer Model used in this study was first developed for grassland systems (Parton et al., 1987, 1988) but has subsequently been updated and enhanced (Metherall, et al., 1993; Parton et al. 1994) and has been used extensively to simulate organic matter and nutrient dynamics in agricultural cropping systems (e.g., Paustian et al., 1992, 1996, 2001; Carter et al., 1993; Parton and Rasmussen, 1994). Century simulates long-term dynamics of carbon, nitrogen, phosphorus and sulfur in the top 20 cm of soil on a monthly basis and has proven to provide reliable estimates of soil C changes (e.g. Smith et al. 1997). Soil organic carbon and nitrogen stocks are represented by two plant litter pools and three soil organic matter pools (termed active, slow, and passive). The crop growth submodel simulates crop growth, dry matter production and yield to estimate the amount and quality of residue returned to the soil, as well as plant influence on soil water, nutrients and other factors affecting soil organic matter turnover. The soil water balance submodel calculates water balance components and changes in soil water availability, which influence both plant growth and decomposition/nutrient cycling processes. A variety of management options may be specified including crop type, tillage, fertilization, organic matter addition (e.g., manuring), harvest (with variable residue removal), drainage, irrigation, burning and grazing intensity. Specifying crop type and management options in the management schedule file simulates the desired cropping sequence. Figure 9 provides an overview of the Century model illustrating the main components of the model. Only carbon and nitrogen dynamics were addressed in this research. Model simulations did not include the occurrence of soil erosion.

To evaluate the model under conditions representative for the Corn Belt Region of the U.S., the model was used to simulate long-term continuous corn and corn-soybean cropping systems at five different locations involving various soil types and climate regimes, involving a total of 29 separate treatments for tillage and fertilization management (Paul et al., 1997) (Lafayette, IN; Lexington, KY; Hoytville, OH; Wooster, OH; and Arlington, WI). To test the model's ability to estimate soil carbon levels and changes due to management without using site-specific information on initial soil C levels, we initialized and executed the model using only climate, soil physical properties, and management driving variables. The model first estimated pre-cultivation soil carbon contents under native vegetation using a stochastic weather generator (based on long-term mean climate) and the physical description for the site, including soil texture

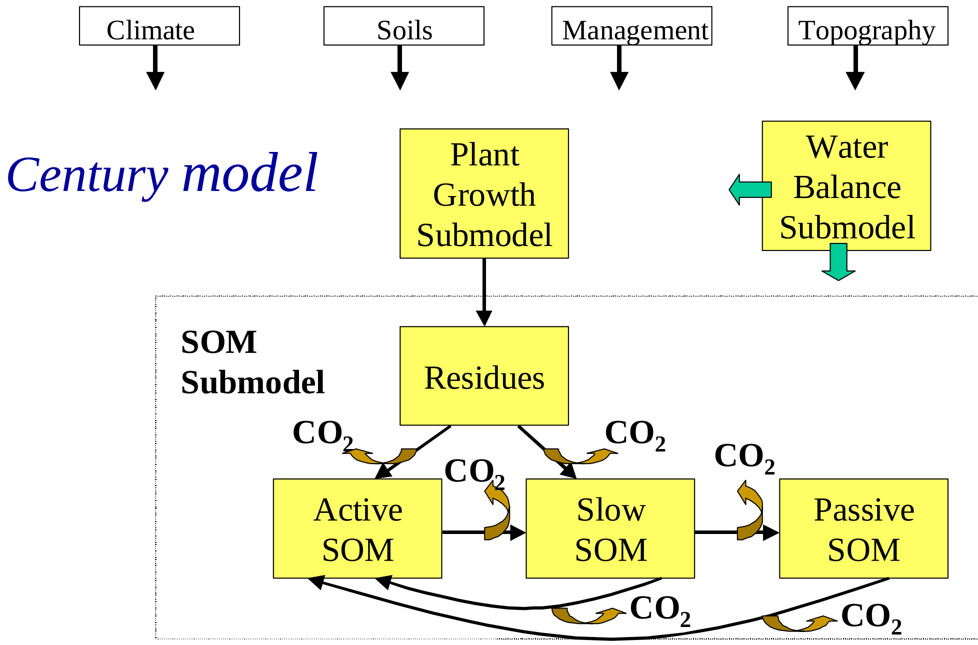


Figure 9: Simplified diagram of major components of the Century model

and soil hydric properties. We assumed the vegetation to be tall grass prairie, which was moderately grazed in the summer months with a fire frequency of three years, and the model was run for 6000 years to approximate steady-state conditions. Next, representative historical practices, as reported by the managers of each of the long-term sites and/or based on published literature, were simulated for the period from initial cultivation (mid to late 1800s) to the start of the field experiment. Observed weather data from the nearest weather station were used for the period of record. Finally, the field experimental period was simulated using the actual management practices for multiple treatments per site, as reported by the site managers (Paul et al., 1997). Most of the experiments have been in place for 20-30 years. Model simulations were run based on these data and compared to measured soil C and crop yields reported for each site. The model explained 85% of the variability across all treatments, sites, and time periods, using all published data from the studies and explained 82% of the variability when looking at only soil C data obtained in 1992 from a cross-site sampling which we conducted (Figures 10 and 11). Comparison of measured and modeled values did not reveal any systematic biases (e.g., associated with particular soil types or management factors) and gives confidence in the generality of the model and it's ability to estimate soil C changes for a range of conditions across the Corn Belt, using a uniform parameterization. For the Phase I and Phase II analysis, we initialized the model in a similar fashion as described above, by first estimating pre-cultivation soil C contents followed by changes due to historical cropping practices up to and including present conditions.

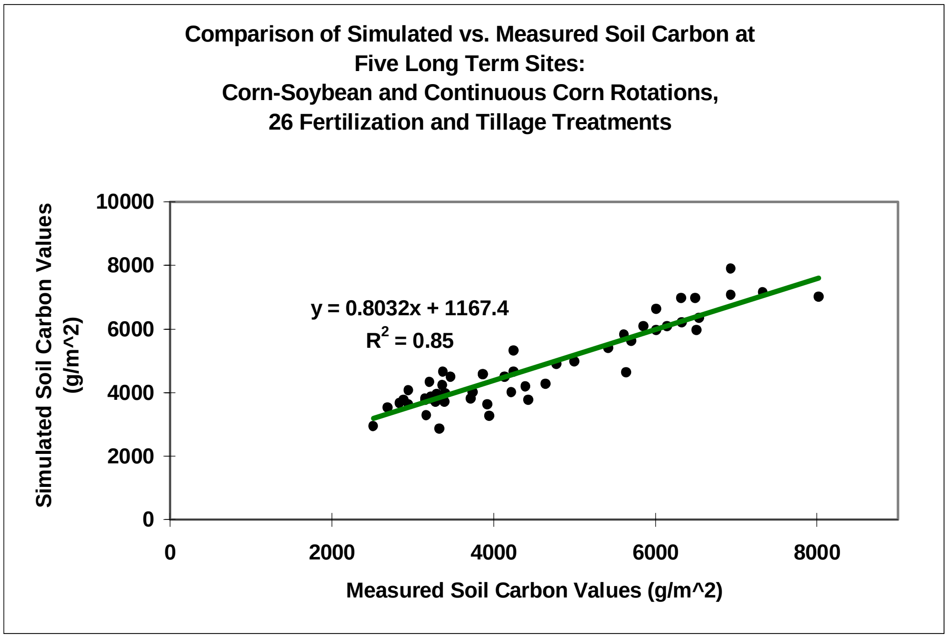


Figure 10: Simulated vs. measured soil C at 5 long term research sites

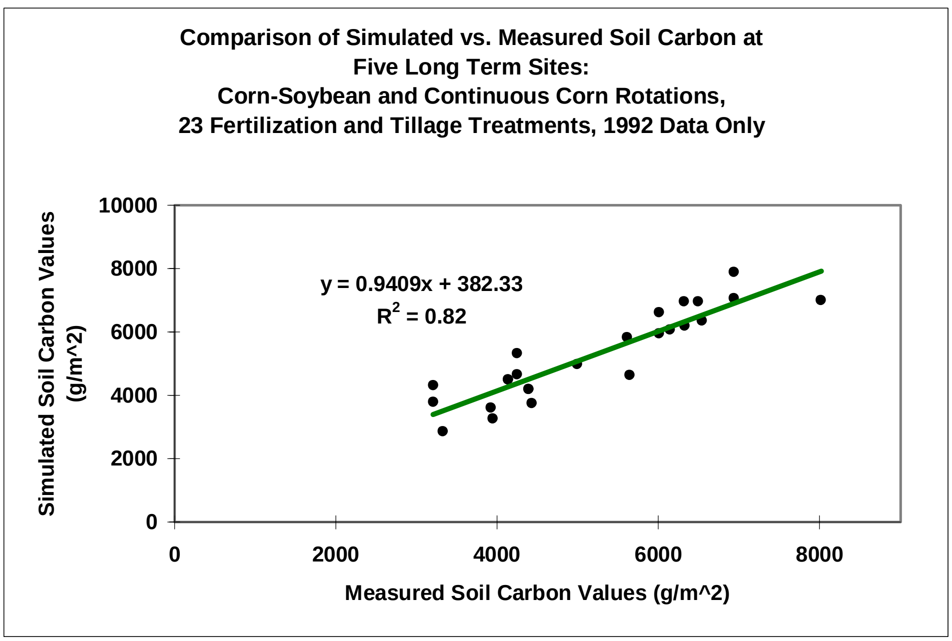


Figure 11: Simulated vs. measured soil C at 5 long term research sites (1992 data only)

Initial Contacts And Expectations

Representatives from Colorado State University, Natural Resource Ecology Laboratory (NREL) and Natural Resources Conservation Service (NRCS) first met with the Nebraska Farm Policy Task Force in 1999. Items discussed include current information on greenhouse gases, on going C studies in the mid-west US using the Century EcoSystem Soil Organic Matter Computer Model (Parton, et al., 1987, 1994; Metherall, et al., 1993) and how a C study in Nebraska could be accomplished. Additional meetings with the state conservation partners took place in the summer and fall of 2000, and discussed the issues of funding, state legislation and the use of various databases. In 2001, cooperative agreements between funding sources, Department of Natural Resources, NRCS and NREL were developed. These agreements detail the responsibilities of each group in providing a C study, the impacts of agriculture on soil C and the potential for Nebraska agriculture to sequester C. The project is divided into two parts. The initial statewide (Phase I) study of cropland utilized existing information on climate, soils and management factors (e.g., irrigation, drainage, crops grown, production levels and tillage systems). These databases were developed for the state, and further explanations are available in the following section of this report entitled, Phase I: Methodology. The detailed county (Phase II) study uses information gathered during the Phase I study, and the Carbon Sequestration Rural Appraisal (CSRA) to collect additional data from local land managers about each individual county (Brenner, et al., 2001, 2002; Paustian, et al., 2002).

Phase I: Methodology

The following sections describe the development of databases needed for the analyses using the Century model. Databases of climate, soils, irrigation and land management were compiled from various sources and enable the modeling of complex agriculture cropping systems across the state. The process provides the state with a compilation of spatially resolved resource information and integrates this information at varying scales from the sub-county to regional. The management data available from existing sources is applicable at the regional scale, but has limited use for the local land manager. Additional data collected for the Phase II assessment provides more complete information at the county level and enables the local land manager to make more accurate estimates of C changes due to land management decisions.

Climate and Soil Databases

Data on climate, soils, land use and management practices used in the analysis were assembled from a variety of sources. Individual counties are the spatial unit for representing climate factors. In other words, counties were assumed to be homogeneous with respect to temperature and precipitation.

Monthly temperature (mean monthly maximum and minimum) and precipitation (monthly total) values were obtained from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) climate dataset (Daly et al., 1994). PRISM uses point data from the U.S. network of weather stations and a digital elevation model (DEM) to orographically adjust climate variables for 4 km grid cells across the coterminous U.S. The data used in our analysis consisted of long-term (1961-1990) monthly averages (Figure 12 & 13). Area-weighted mean values of monthly temperature and precipitation variables were calculated for each county.

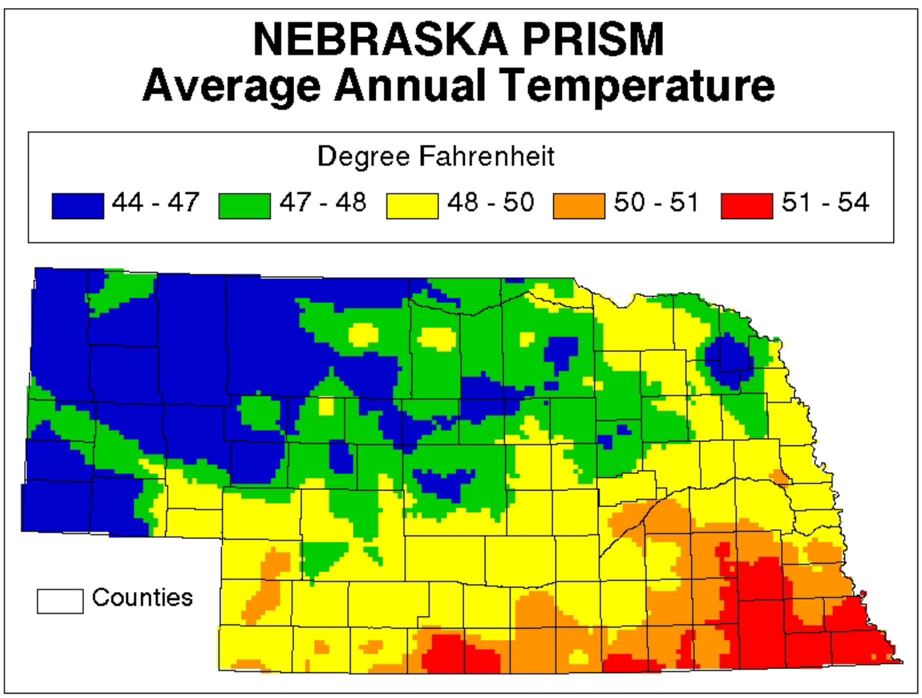


Figure 12: PRISM Average Annual Temperature (1961-1990)

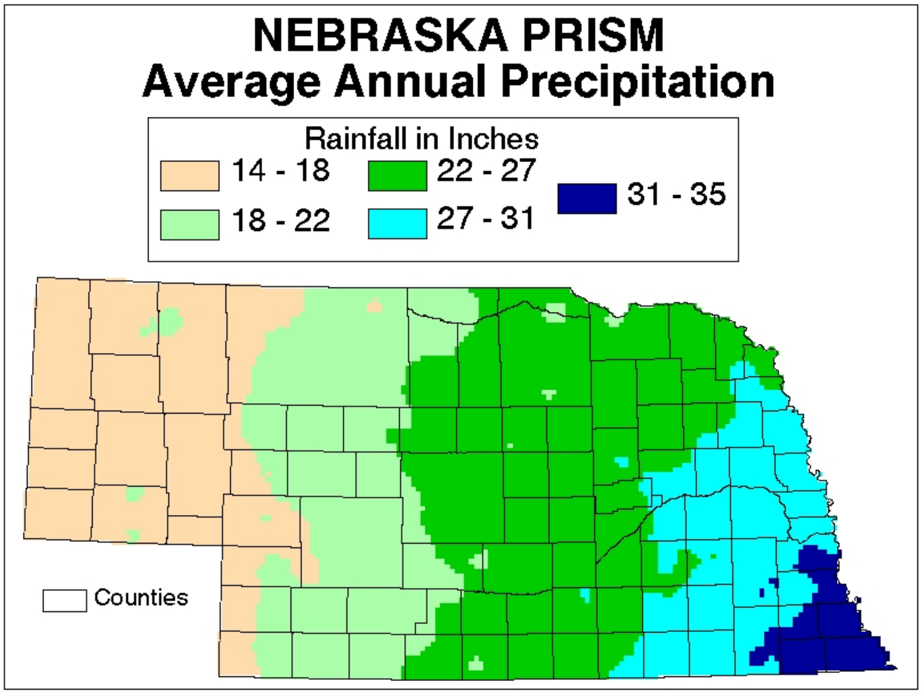


Figure 13: PRISM Average Annual Precipitation (1961-1990)

County-level soil attributes were derived from analysis at the component level (i.e., soil series) within soil associations of STATSGO (USDA-SCS, 1994). For each county, area-weighted frequency distributions of sand, silt, and clay were determined based on the relative proportion of component soils within each soil association (Figure 14-16). Soil types for application in the model were grouped according to surface texture (0-20 cm) and classification as hydric (poorly drained) or non-hydric (well-drained) soils (Figure 17 and 18). Within each county, all soil types with an area greater than 90 hectares (~222 acres) are included in the analysis, except for areas where crops cannot be grown, such as rocky outcrops and water. This procedure provided 750 county- soil combinations in the state. Figures 19 and 20 are examples of the soil types that were included in the analysis for Adams and Lincoln Counties. Identification of major soil types yielded two to thirteen distinct soil/hydric combinations per county with 70 of the counties having six to ten distinct soil/hydric combinations.

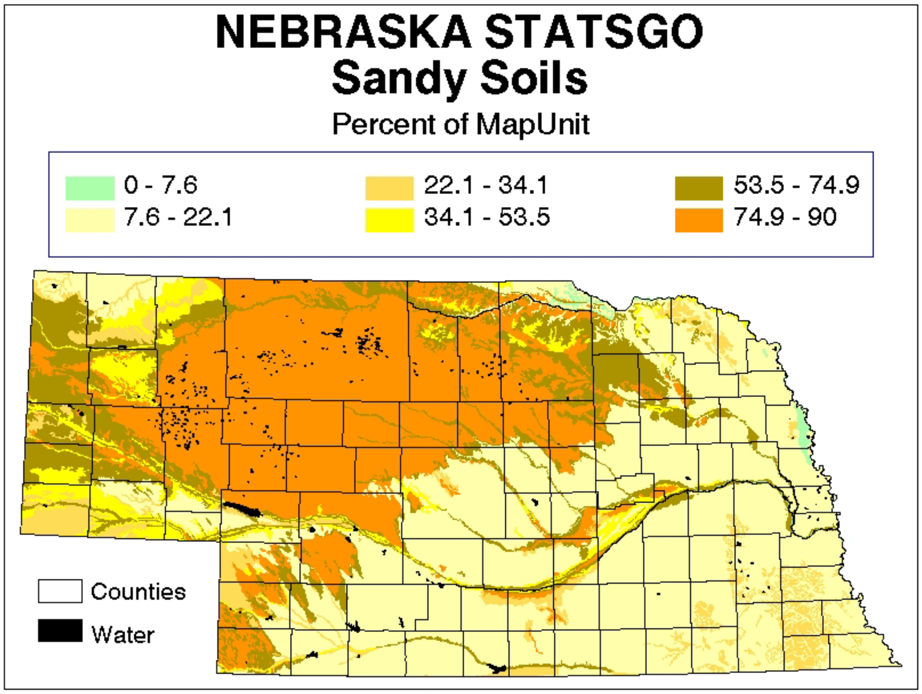


Figure 14: STATSGO Sandy Soil Distribution

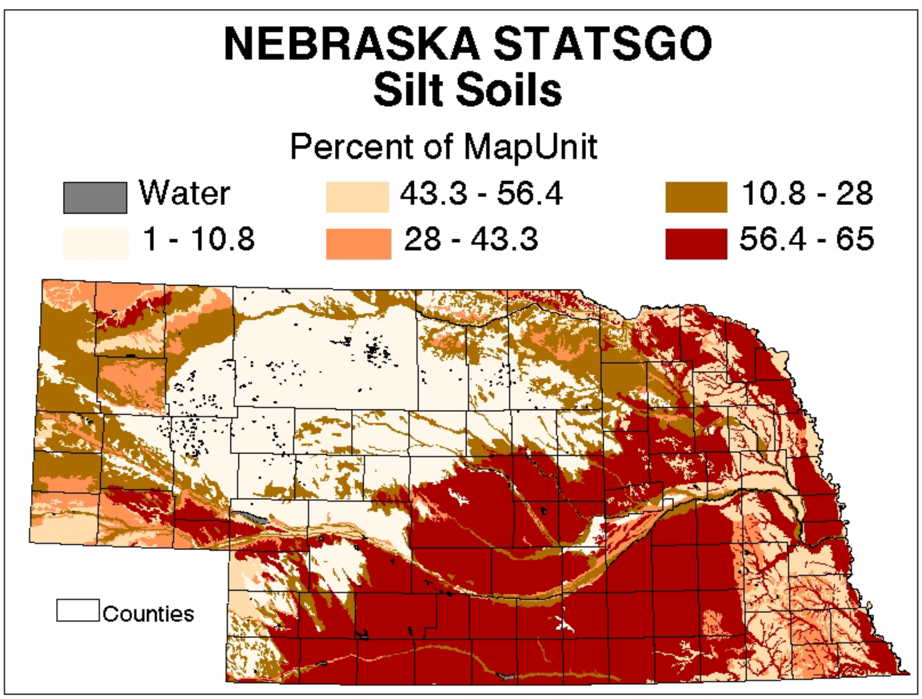


Figure 15: STATSGO Silty Soil Distribution

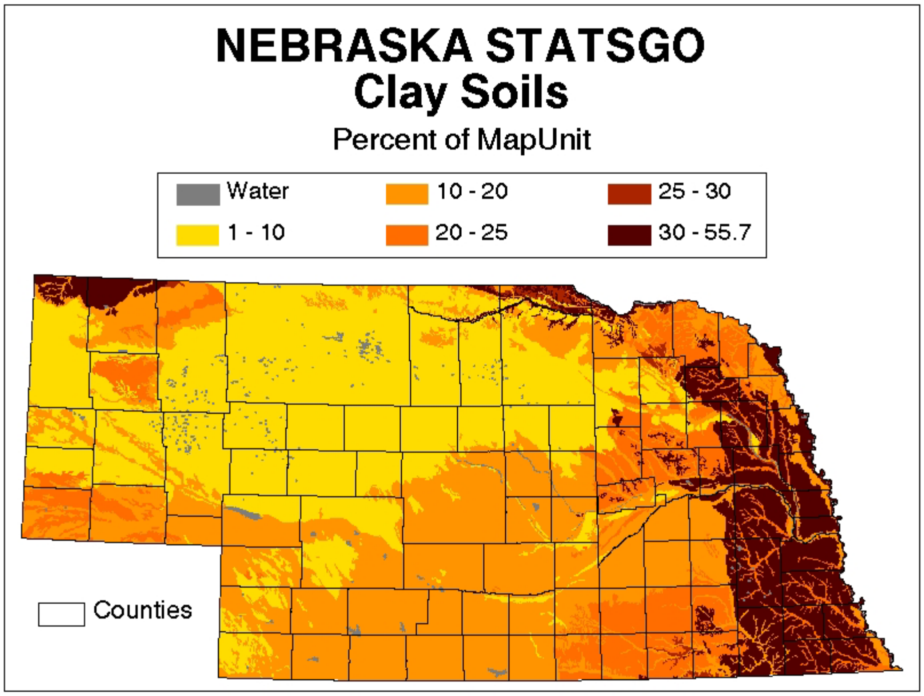


Figure 16: STATSGO Clay Soil Distribution

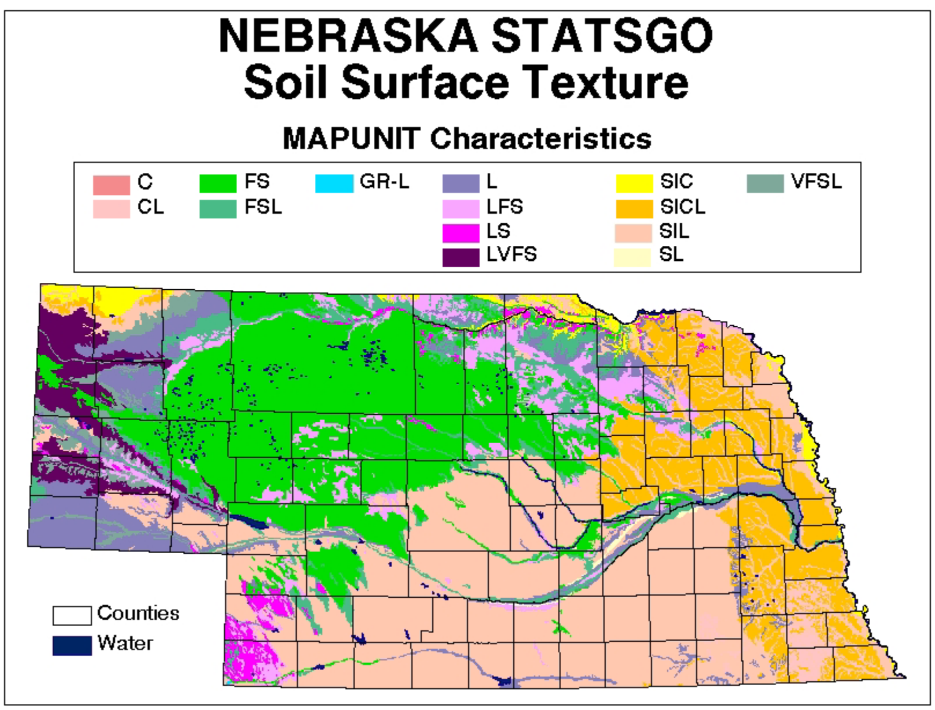


Figure 17: STATSGO Surface Soil Texture Distribution

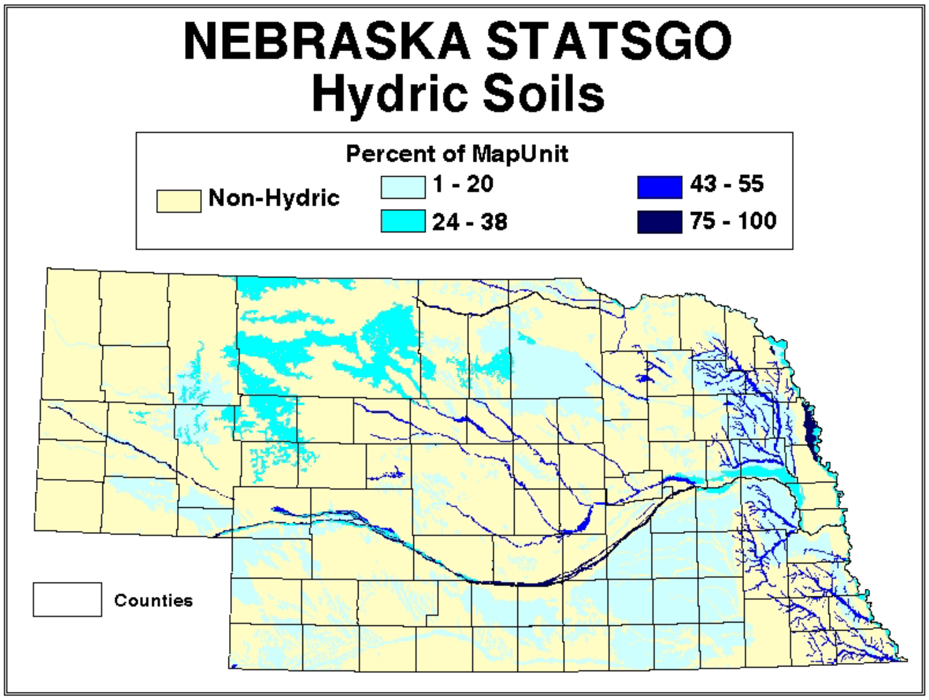


Figure 18: STATSGO Hydric Soil Distribution

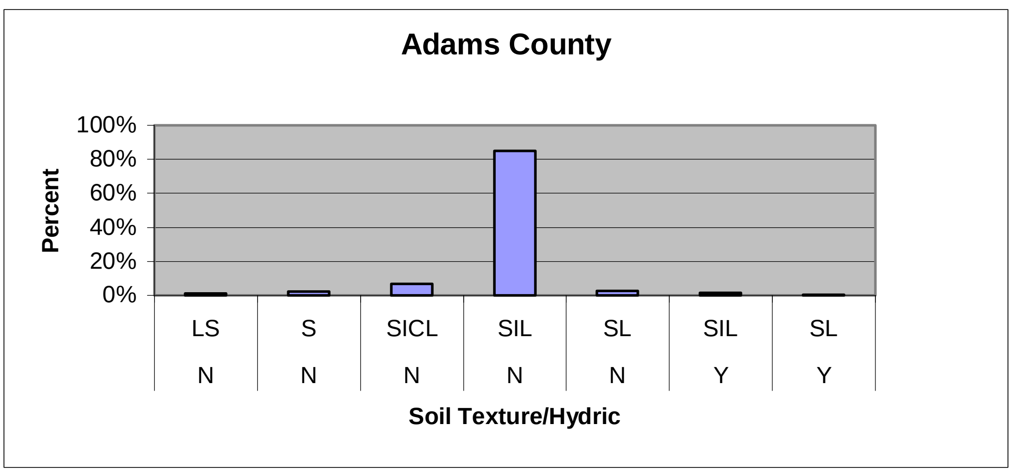


Figure 19: Adams County Modeled Soil Textures

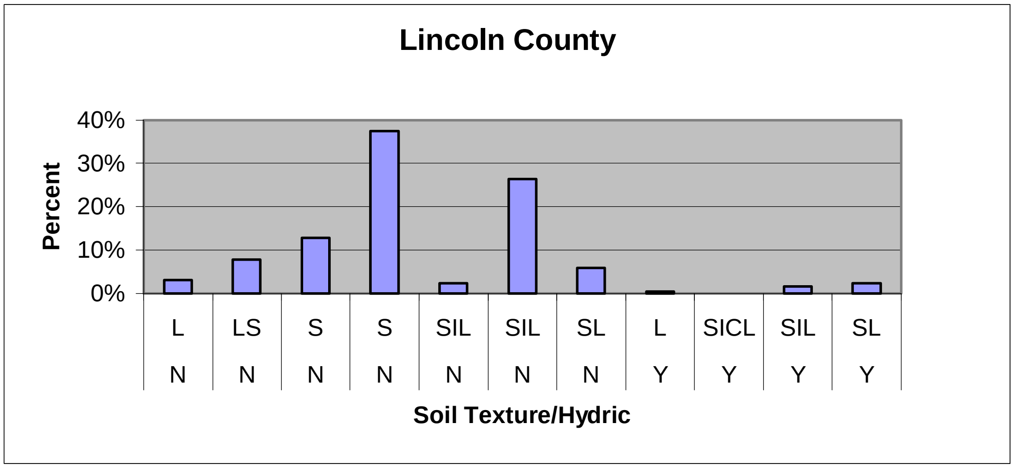


Figure 20: Lincoln County Modeled Soil Textures

GIS Analysis and the Carbon Model: Irrigated Land Geospatial Database

The Century model is able to address irrigation impacts on soil C and this study addressed irrigation as one of the land use inputs into the model. To meet the requirements for the carbon model, Geographic Information Systems (GIS) were utilized as a means to analyze and assimilate several land use layers into the final statewide irrigated land use coverage. Complete details are detailed in Appendix A of this report.

The Nebraska GAP (GAP, 1993) statewide land-cover grid map was obtained from the GAP Analysis Project. This data is developed with rigorous standards from 1993 Landsat TM imagery, unfortunately, it contained no irrigation information. The most accurate irrigation dataset for the state of Nebraska, the COHYST coverage, is a 43 county pivot and surface irrigation inventory for the Central Platte River Basin. Landsat TM data from 1997 was utilized in the development of the map, and twenty-three of the counties were field checked for accuracy. Because this data layer does not include all of the counties within the state of Nebraska, it could not be used solely as the statewide irrigation layer for the analysis. Wilhelmi (1999) developed, a statewide pivot and surface irrigation map using 1990 Landsat TM imagery. This irrigation layer was used to supplement the missing areas to complete a statewide coverage.

Preliminary analysis of the GAP and COHYST data indicated a high degree of correlation between the spatial features. The circular cropland features from the GAP coverage associated with pivot irrigation, coincided with the majority of the COHYST pivot features. Because of this correlation, the COHYST data set and the GAP data set were both regarded as being correctly georeferenced.

Because the Wilhelmi data set was generated using on-screen digitizing in ArcView with no field verification, it was compared to the COHYST and GAP cropland areas. Inconsistencies were found in the southwest portion of the state where the Wilhelmi map was significantly misaligned in relation to cropland areas extracted from the land cover data set and irrigated areas from the COHYST theme. Further inspection of the data indicated that many of the irrigation polygons are distorted. Certain areas were digitized as large irregular shapes instead of individual polygons as compared to the COHYST layer. The data set is missing attribute values that determine irrigated, non-irrigated, and no data polygons and has no distinction between surface and pivot irrigation types in the coverage. The Wilhelmi data set was developed using the Albers Equal-Area projection, and this projection is problematic for states that lie in an east/west plane. Additionally, the Alber's projection parameters were incorrectly set causing a displacement error in the dataset.

The combined data sets were corrected using numerous GIS vector and raster methodologies that consumed many man-hours and computer processing cycles. Issues dealing with differently geo-referenced data, dissimilar projections, unmatched attribute tables, and inaccurate data all had to be addressed before the datasets could be used to provide the necessary inputs to the Century model.

This spatial integration resulted in two useful products including a single statewide surface irrigation coverage (The Nebraska Pivot and Surface Irrigation (NIMDS) map) and a statewide irrigated land use grid called the Nebraska Irrigated Land Use/Land Cover raster dataset (Figure 21). The final land cover map was used to produce the land use input for the Century model for the State of Nebraska. Land use/land cover classification categories and statistics are documented in Table 1.

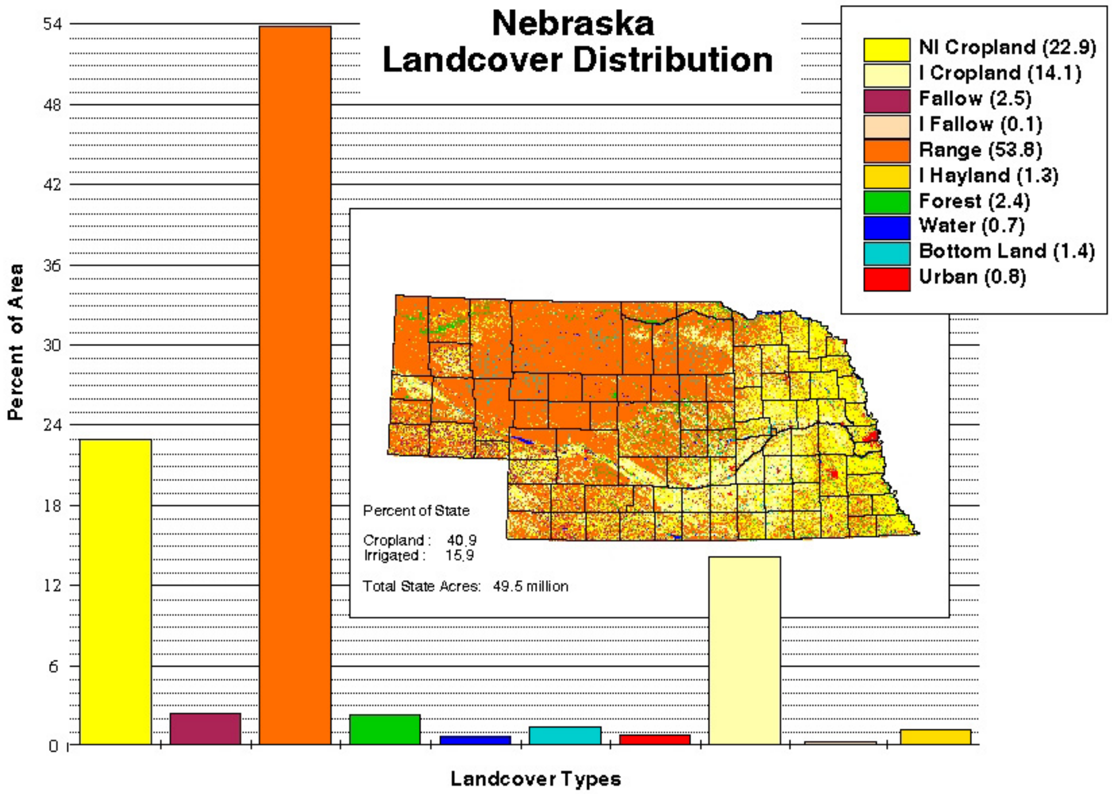


Figure 21: Nebraska Land Cover Distribution

Table 1: Land Use/Land Cover Areas.

Classification	Area (Hectare)	Area (Acre)	Percentage of State Land Area
Non-irrigated Cropland	4,579,911	11,312,380	22.9
Irrigated Cropland	2,824,404	6,976,277	14.1
Fallow	499,279	1,233,220	2.5
Irrigated Fallow	21,000	51,871	0.1
Range	10,783,259	26,634,649	53.8
Irrigated Hayland	262,394	648,113	1.3
Forest	472,074	1,166,024	2.4
Water	145,519	359,433	0.7
Bottom Land	278,921	688,936	1.4
Urban	169,270	418,097	0.8

Cropping Histories And Land Management

The Century model is capable of estimating 'initial conditions' – in other words determining a starting point – for use in land management scenarios. This is an extremely powerful attribute of the model and our analysis approach, for two reasons. First, there are at present no spatially distributed measurements of soil carbon stocks, for known time periods, that can be used as an empirical starting point (this is true not only for Nebraska but for any other state in the US). While soil maps do contain information about the general distribution of soil carbon at state and county levels, soil carbon values represent 'interpreted' values that do not explicitly consider land use and for which the soil pedons used for determining map unit attributes may differ by several decades in when they were measured. Secondly, using the model together with historical land use information incorporates the effects of previous management practices on soil organic matter pools in a consistent and robust way.

The information on historical cropping practices used for Century simulations was gathered from a variety of sources with differing scales of coverage, from the experiences of a single farmer (Miner 1998) to national level databases (NASS, 2000). Figure 22 illustrates how national databases provide state and county values and trends for crops grown over time.
The goal was to gain as much knowledge as possible from the time of plow out and the "pioneer" stage of subsistence farming (Hurd, 1930; Latta, 1938; Iowa State College Staff Members, 1946; Bogue, 1963; Cochrane, 1993; Hurt, 1994; Sisk, 1998) until modern farming regions and practices (CTIC, 1998; NASS, 2000; NRI, 1997). Information on individual crops (Piper et al., 1924; Hurd, 1929; Hardies and Hume, 1927; NASS, 2000) and early crop rotations was gathered from literature dating as far back as the horse-drawn era of the late 1890s (Holmes, 1903; Spillman, 1906; Chilcott, 1910; Smith, 1912; Kezer, ca 1920) through the emergence and eventual dominance of today's technologies (Leighty, 1938; Hargreaves, 1993; NRI, 1997). Data was accumulated on the changing uses of manure and inorganic fertilizers (Brooks, 1901; Anonymous, 1924; Fraps and Asbury, 1931; Ross and Mehring, 1938; Saltzer and Schollenberger, 1938; Ibach and Mahan, 1968; Alexander and Smith, 1990). A recent Carbon Sequestration Rural Appraisal (CSRA) of county-level cropping histories in Iowa was used to check MLRA-level histories for Century (Brenner, et al., 2002). While minor adjustments were made to the Century histories, agreement was good. Many early studies of cropping systems by region were investigated (Spillman, 1903, 1908, 1909; Warren, 1911; Larson et al., 1922;

Russell et al., 1922; Elliot et al., 1928; Ellsworth, 1929; Garey, 1929; Holmes, 1929; Hodges et al., 1930; Bonnen and Elliot, 1931). One such study by Elliot (1933), subdivided the United States into 14 major farm types and over 500 sub-regions.

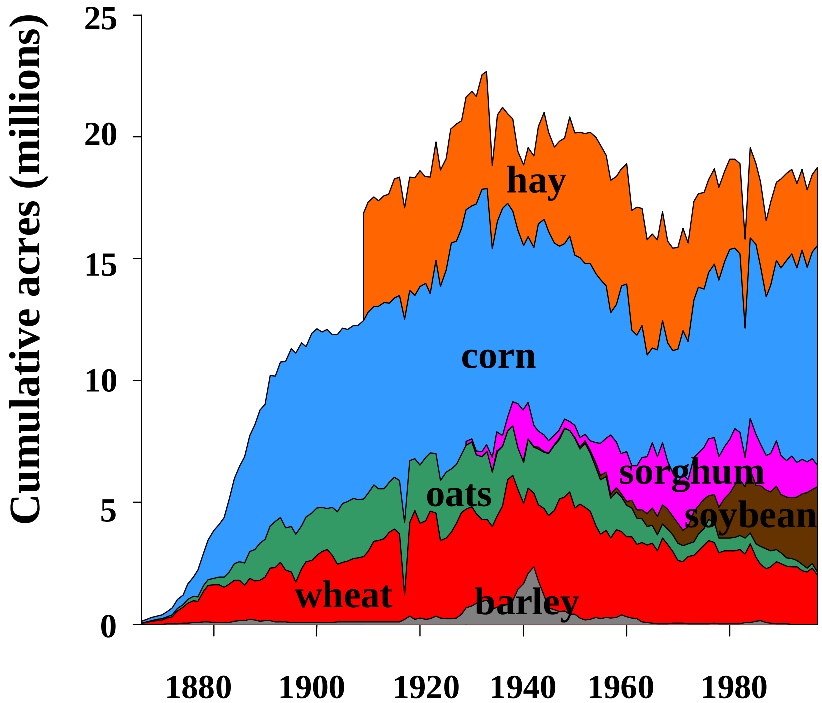


Figure 22: Crop Changes From Plow Out To Present (Hay was not recorded until 1910).

The state was divided in thirteen regions based on major land resource areas (MLRA's) as defined by USDA-NRCS (Figure 23). The irregular boundaries of these regions were rectified to follow county boundaries, based on area weighting and the judgment of NE NRCS technical specialists in selecting the single most representative MLRA for counties associated with more than one MLRA (Figure 24). Alignment with county boundaries was important to allow intercomparisons with the Phase II study, which was done at the level of individual counties. The modified MLRAs provided the basis for the development of cropping and management systems within each region. MLRA 65 was subdivided into an east and west region to account for the land use change from rangeland to irrigation in the western part of the Sand Hills. Histories have been constructed on modified MLRA regions for use with the Century model in an attempt to closely chronicle the opening of the agricultural lands, the changes in dominant crops, tillage practices, residue management and inputs to the soil (Table 2).

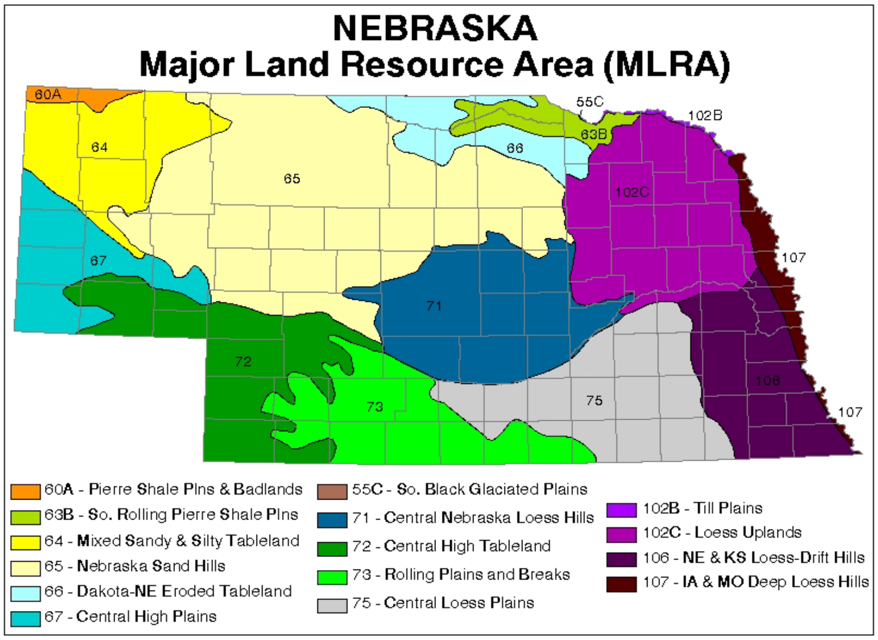


Figure 23: Major Land Resource Areas (MLRA)

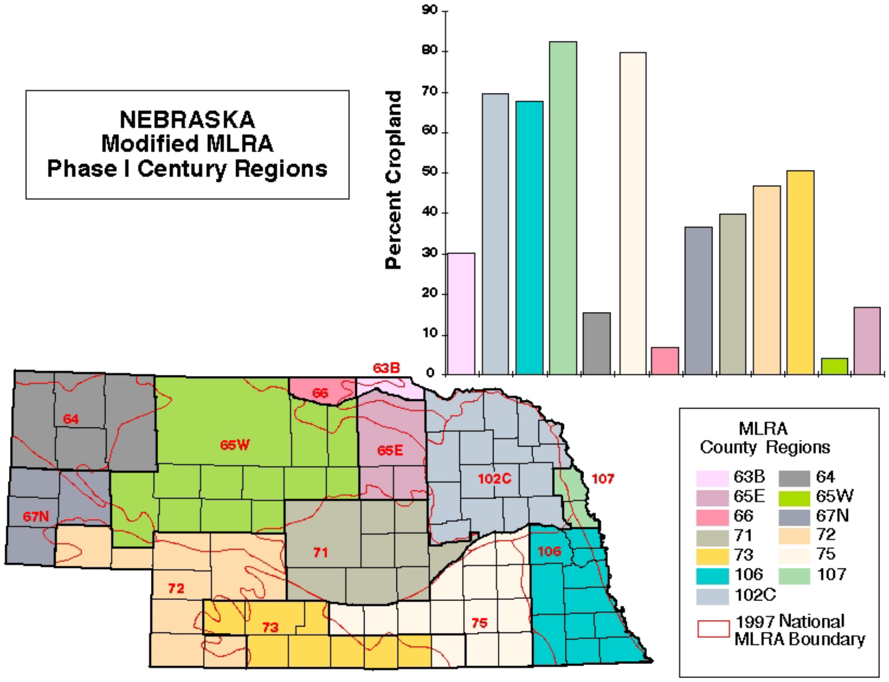


Figure 24: Nebraska Modified MLRA Regions

Table 2: Historic Crop Rotations by NE Modified MLRA Century Regions.

Modified MLRA	Crop Rotations	Time Period
63B	W-F	1891-1970
64	W-F	1884-1970
65E	P-P-F	1873-1970
65W	Pasture	1879-1970
66	C-O-H C-O	1879-1938 1939-1970
67	W-F	1881-1970
71	C-O-H C-O	1879-1938 1939-1970
72	W-W W-F	1881-1938 1939-1970
73	W-W	1879-1970
75	W-W	1874-1970
102C	P-P-F	1873-1970
106	C-O-H C-C-O C-C	1863-1904 1905-1922 1923-1970
107	C-C-C-O-H-H C-C-O	1861-1932 1933-1970

C= corn; F=fallow; H=hay; O=oats; P=spring wheat; W=winter wheat

Modern Crop Histories and Land Management

Modern crop rotations (1970- present) were developed for each modified MLRA based on 1997 NRI data. The most recent NRI reports cropping history from 1997, back to 1979 (i.e. three years prior to the first inventory base year, 1982) and we extrapolated this information further back to 1970. Crop rotations modeled include both non-irrigated and irrigated systems. To represent the change in land management due to the Conservation Reserve Program (CRP), the non-irrigated crop rotations were also modeled showing the conversion to grass starting in 1986. Modern irrigation using center-pivot technology was represented in the model starting in

1970. Irrigation was modeled by assuming that water applied was sufficient to meet full crop demand (i.e., irrigation plus precipitation equaled potential evapotranspiration during the growing season). Region 65W is an area where rangeland was converted to irrigated cropland in the 1970 and is dominated by the continuous corn crop rotations with lesser amounts of other irrigated crop rotations. Table 3 details the crop rotations and whether irrigation was modeled for each region.

Three tillage regimes (intensive tillage, moderate tillage and no tillage), were simulated for each rotation from 1986-2000 in each county. All prior cultivation was assumed to have been using intensive tillage. Intensive tillage was defined as multiple tillage operations every year, including significant soil inversion (e.g., plowing, deep disking) and low surface residue coverage. This definition corresponds to the intensive tillage and 'reduced' tillage systems as defined by Conservation Technology Information Center (CTIC, 1998). No tillage was defined as not disturbing the soil except through the use of fertilizer and seed drills and where no-till is applied to all crops in the rotation. Moderate tillage made up the remainder of the cultivated area, including mulch tillage and ridge tillage as defined by CTIC and intermittent no-till. After year 2000, scenarios for use of no-till on all crop rotations, except non-irrigated wheat-fallow, were run to estimate potential carbon sequestration due to change in tillage management. The wheat-fallow rotation became a wheat-corn-fallow crop rotation under no tillage management system to reflect intensification of the cropping system.

While in some respects the approach used in representing agricultural ecosystems may seem highly oversimplified for a state as diverse as Nebraska, it is important to note that even this level of simplification of management systems, when combined with different soil and climate conditions across the state, results in tens of thousands of unique combinations that are simulated in the model. Thus we've attempted to strike a balance between representing the dominant features of NE agricultural systems that affect soil carbon dynamics and keeping the number of analyses and amount of data within manageable limits. In the phase II study described later, the collection of additional county-level data motivated the use of a more detailed analysis, resulting in approximately one million simulation runs to estimate soil C changes.

Table 3: Modern Crop Rotations By NE Modified MLRA Century Regions.

Modified MLRA	Crop Rotations	Irrigation
63B	C-C C-B C-S CRP	Y N N N
64	W-F O-W CRP	N N N
65E	C-B C-C-H-H-H-H C-B CRP	Y N N N
65W	C-C C-C-S C-C-H-H-H-H	Y Y Y
66	C-C C-B C-B CRP	Y Y N N
67N	C-C W-F CRP	Y N N
71	C-C C-C CRP	Y N N
72	C-C W-F CRP	Y N N
73	C-C W-F S-W-F CRP	Y N N N
75	C-C C-B W-W S-W CRP	Y Y N N N
102C	C-B CRP	N N
106	C-B S-B CRP	N N N
107	C-B CRP	N N

C= corn; B=soybean, F=fallow; H=hay; O=oats; S=sorghum; W=winter wheat; CRP=conservation reserve grass planting

Phase I: Results

Century Modeling and Analysis

Initial model parameters were set according to the procedure outlined in the Modeling Soil Organic Matter section of this report. The equilibrium Century runs provide the initial soil organic matter levels in the different pools. The model then simulates the change in soil C as a function of past agricultural practices as described in the Cropping Histories and Land Management section of this report. Modern agricultural practices are simulated as described in the Modern Crop Histories and Land Management section of this report. To simulate changes due to the Conservation Reserve Program (CRP), all non-irrigated crop rotations, under intensive tillage, were modeled with a change to CRP grass plantings starting in 1986. Drainage of hydric soils occurred in two phases; the first phase being a partial drainage in the early 20th century, and more complete drainage in 1970. It was assumed that irrigation systems are not used on hydric soils. Each model run is associated with a specific soil texture and mean climate for each county.

CTIC reports the area in various tillage systems by individual crops on an annual basis; however, it does not differentiate between long-term no tillage practices versus intermittent or ‘rotational no tillage' (e.g., tilled corn – no-tilled soybean rotations). For agronomic reasons, (i.e., low residue amounts under soybean and use of herbicide-resistant soybeans), the percent area of soybeans managed under no-till was generally higher than for corn.

Thus, to estimate the area of corn rotations in each county of continuous no tillage as opposed to moderate tillage, we based the percent area of continuous no tillage on the acreage of corn under no tillage, assuming that if corn were no-tilled, it was likely that other crops in the rotation (e.g., soybean or oats) would also be no-tilled. The remaining area reported as no tillage by CTIC was assumed to represent no tillage every other year and was included as part of the moderate tillage category. The moderate tillage category also included areas reported as mulch-till and ridge-till by CTIC. The area under intensive tillage was then calculated by difference. To estimate the area of wheat rotations in each county of continuous no tillage, we based the percent area of continuous no tillage on the acreage of wheat under no tillage, assuming that if wheat were no-tilled, it was likely that other crops in the rotation (e.g., corn, oats, sunflowers) would also be no-tilled. The remaining area reported as no tillage by CTIC was included as part of the moderate tillage category. The moderate tillage category also included areas reported as mulch-till and ridge-till by CTIC. The area under intensive tillage was then calculated by difference. This procedure was followed to account for the other crop rotations modeled in each county.

Estimated C Sequestration

It is estimated that current conservation practices are sequestrating 1.7 million tonnes (1.9 million tons) of C annually. This statewide analysis only addresses cropland and is based on our ability to estimate past land use histories, current cropping and tillage systems. This estimate includes the impact of CRP and reflects lower C sequestration rates occurring on these lands due to the length of time they have been managed as a grass system. We estimate that slightly over 3 million hectares (7.5 million acres) of Nebraska is being currently irrigated, 4.7 million hectares (11.6 million acres) is currently in non-irrigated cropland and 0.5 million hectares (1.2 million acres) are in CRP. These areas were distributed to the three tillage systems (intensive tillage, moderate tillage and no tillage). The modeled C changes for each system in each county were joined and provide the C sequestration rates for the different systems. We also estimate that by intensifying cropping systems in the wheat-fallow rotations and going to a no tillage farming systems for all Nebraska cropland will sequester a total of 2.3 million tonnes (2.5 million tons) of C annually over 10 years. It should be noted that this increase of 0.6 million tonnes (0.7 million tons) of C is offsetting lower C sequestration rates from CRP and continuing no tillage systems.

Phase II: Methodology

Introduction

The Nebraska conservation partners recognized that the information gained from the Phase I activities needed to be refined and local land managers needed a tool to estimate C sequestration rates for their system that would allow individuals to estimate soil C changes based on land management decisions. Figure 25 is a flow diagram of the conservation partners involved in this project and details how the involved parties communicated and the process of how data is transferred between groups. NRCS and NRD's were the lead groups in data collection using the Carbon Sequestration Rural Appraisal (CSRA). Natural Resource Ecology Laboratory (NREL) and NRCS staff in Fort Collins, CO, provided database development, modeling expertise using Century and scientific oversight of the project.

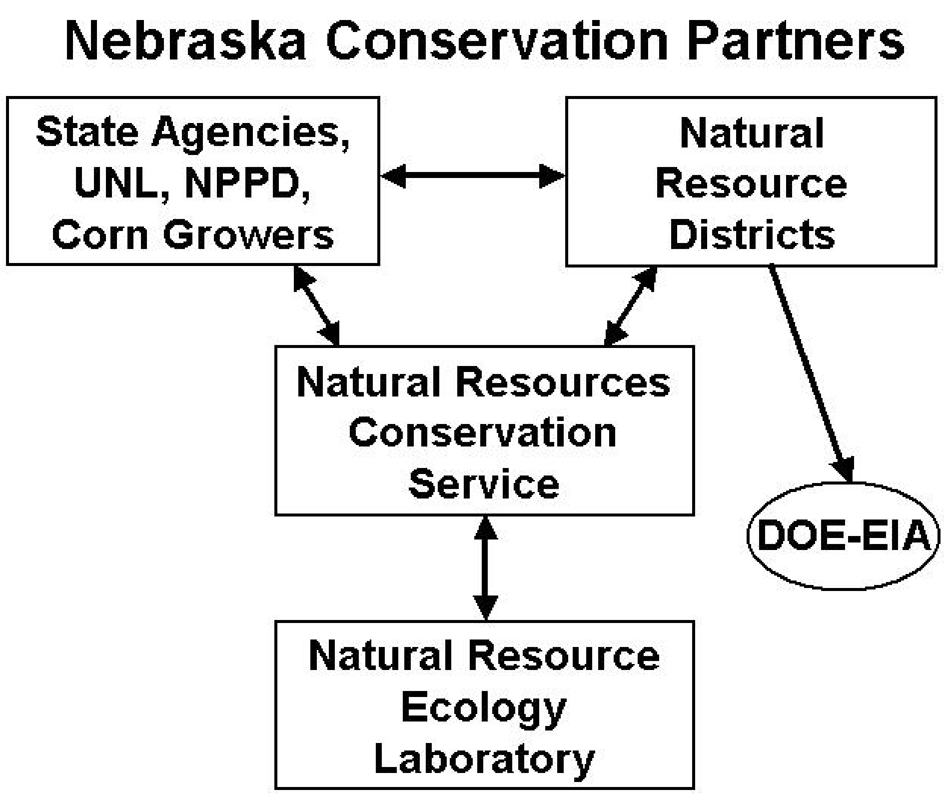


Figure 25: Nebraska conservation partners

Nebraska NRCS compiled the CSRA's and coordinated the Phase II activities used to collect the additional data not available in existing databases. Details of the CSRA process are explained in the Phase II CSRA Data Collection section of this report. All 93 counties and 23 NRD's were provided training in 2001 on the issues of C sequestration, greenhouse gases and how to provide local management information using the CSRA. All 93 counties participated in the data collection and returned completed appraisals to NREL for use in the Century Model simulations. Figure 26 summarizes the CSRA process.

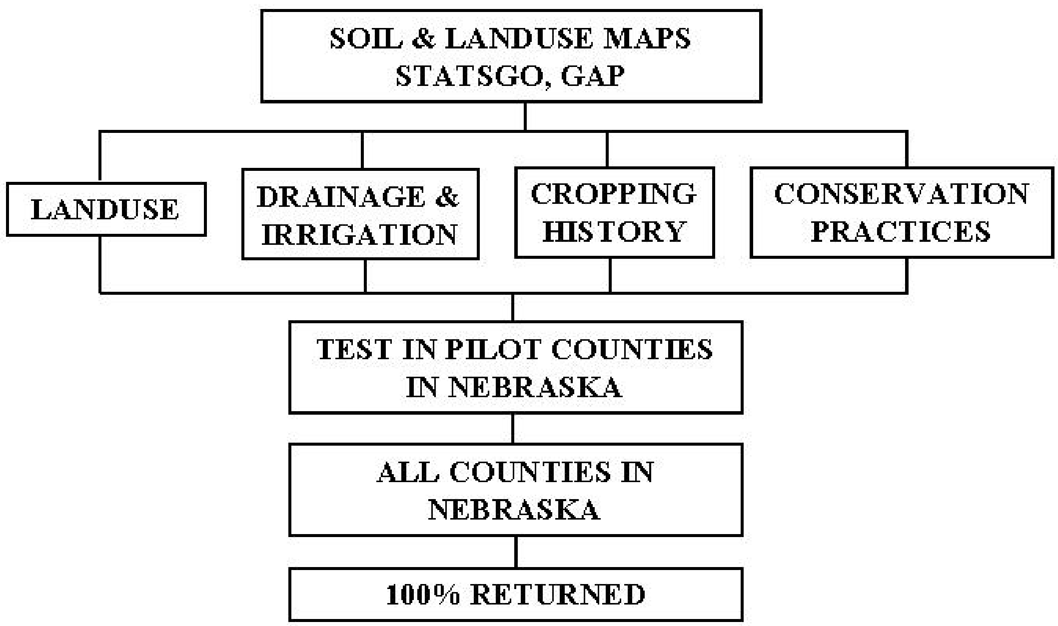


Figure 26: CSRA process

CSRA Data Collection

The CSRA consists of a series of data sheets detailing historical land-use, dominant management practices (drainage, irrigation, crop rotations, tillage and fertilization) over time, and installation of conservation practices (e.g., CRP, grassed waterways, buffers) compiled by local experts in each county. This procedure was successfully used in Iowa and Indiana to gather data from conservation districts (Brenner et al., 2001, 2002). A two-county pilot study was conducted to validate the availability of local data and the willingness of natural resource districts to provide data and to further refine the process of collecting local data at a very large scale for all 93 counties. Chase and Cheyenne Counties participated in the 2001 pilot study. Information and ideas provided by the NRD's and NRCS people in the pilot counties were used to finalize the CSRA format.

To assist the local people in completing the CSRA, individual county maps were developed using STATSGO Map Unit IDentifier (MUID) in each county for the soils information and the Nebraska Land Cover Distribution (Figure 22) as described in the Phase I section of this report. These individual county maps detailed the soils, specific land cover including irrigated and non-irrigated cropland and the area within each category. Dakota County (Figure 27) and Cheyenne County (Figures 28) provide examples of these maps and the variability from east to west of land use within the state.

CSRA as used in Nebraska was an Excel spreadsheet containing a series of work sheets. Excel spreadsheets were electronically transmitted from Fort Collins to Nebraska, completed at the local level and electronically transmitted back to Fort Collins. Table 4 details the types of data provided by the NRD's through the use of the CSRA.

Table 4: Types of data provided by the CSRA

Title	Description
Current Land Use Information	Land use by soil map unit (crop & grass)
Drainage Information	Installation of drainage by soil map unit and date
Irrigation Information	Installation of irrigation by soil map unit and date
County level farming histories	Cropping, fertilizer and tillage practices
Annual conservation practices	Conservation practices installed

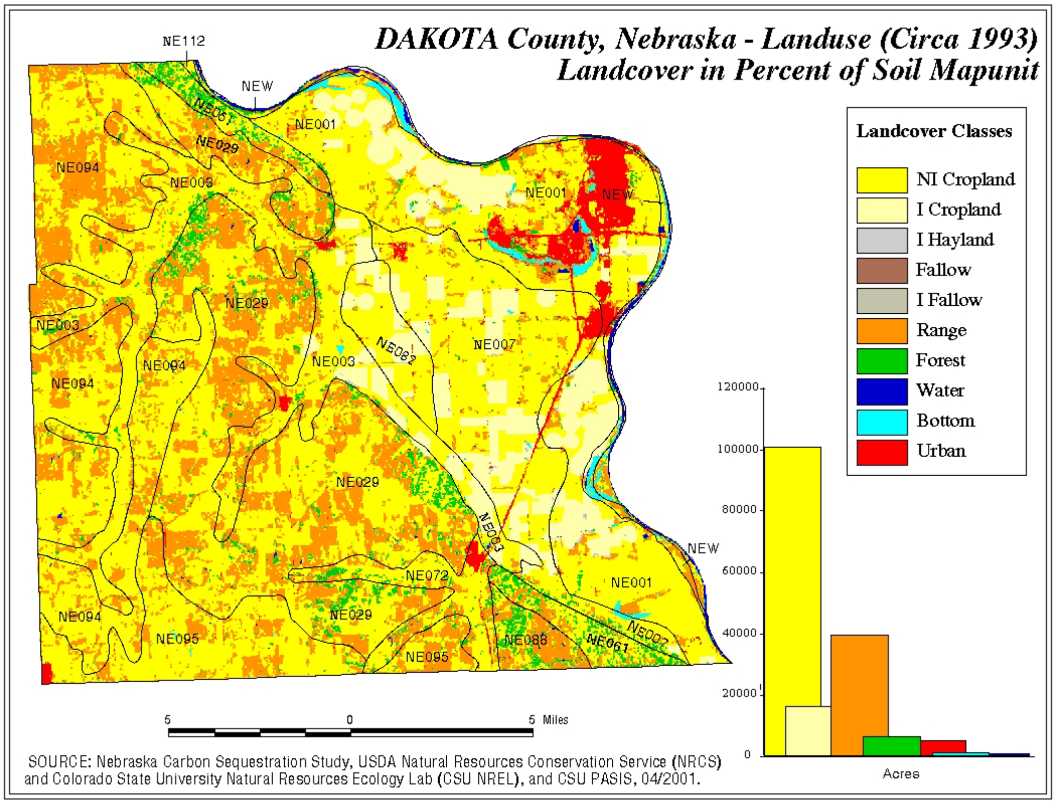


Figure 27: Dakota county STATSGO soil and Nebraska Land Cover Distribution

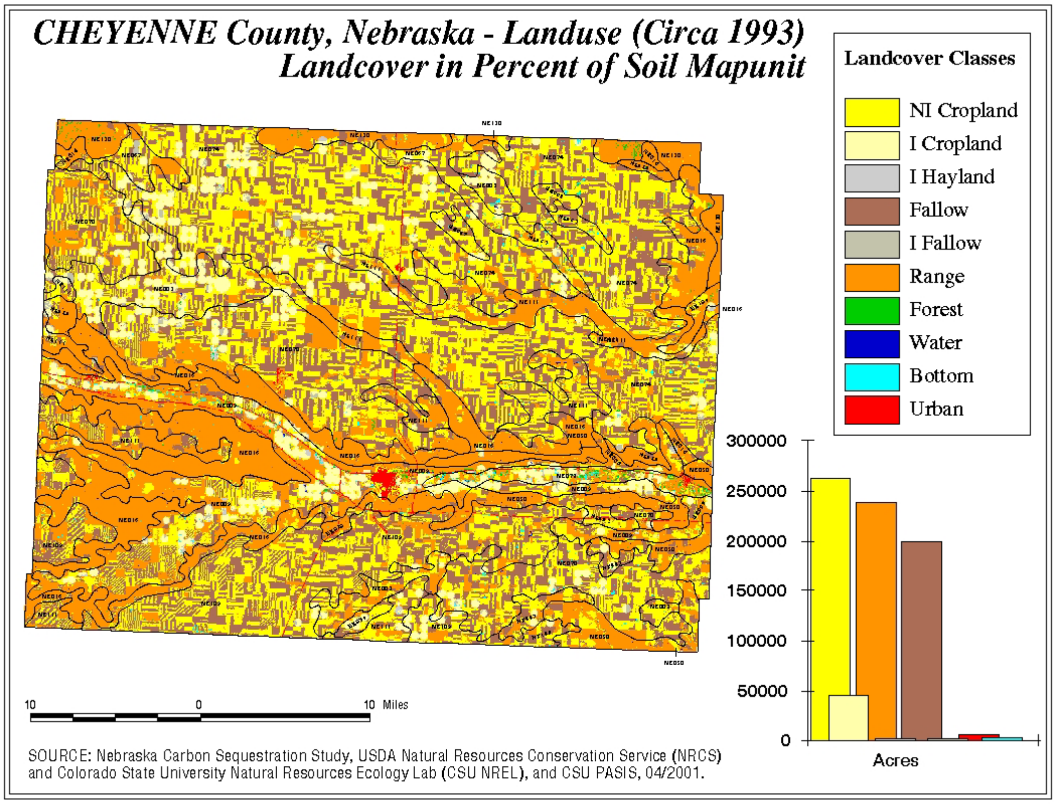


Figure 28: Cheyenne county STATSGO soil and Nebraska Land Cover Distribution

The CSRA data collection process utilized our experiences in Iowa and Indiana to design the process, but it was quickly recognized that Nebraska agriculture had additional issues and questions that required more data. These include the non-irrigated and irrigated cropland issues, non-irrigated cropland using fallow in the rotations and large areas of grazing lands. Additional information was gathered at the county level to address management decisions necessary for crop production including irrigated or non-irrigated crop rotations including fallow periods, fertilizer rates and timing, tillage events and timing, crop yields, conversion of cropland to grassland, conversion of grassland to cropland and condition of grazing lands. An example of some of the sheets is illustrated in Appendix B. This additional data collection provided challenges in designing the CSRA to capture these new issues and to standardize the data collection process. It was also recognized that the local land managers needed support data available from national datasets to assist them in the completion of the CSRA.

To assist in the quality control of the CSRA data, it was necessary to provide consistent terminology, definitions, and units between counties. Quality control was also necessary to ensure similarity between CSRA and other published data where appropriate. Developing tools to analyze and compare these data took a substantial amount of effort. The CSRA spreadsheets are supported by background information from published databases. These other sources include USDA Conservation Reserve Program (CRP) contract acreage obtained from USDA Farm Services Agency (USDA-FSA, 2000); National Agricultural Statistics Service (NASS, 2000) county level acres harvested and yield data obtained from <http://www.usda.gov/nass/>; and annual residue management data obtained from the Conservation Technology Information Center (CTIC, 1998) through their electronic data access and retrieval system called WinCEDAR.

Two Excel spreadsheets with multiple worksheets were developed to automatically consolidate data from submitted CSRA sheets, CTIC data, NASS data and CRP data. All data was consolidated at the county level. Most of the data was also consolidated at a yearly level during the late 1980's and through the 1990's.

Conservation Reserve Program (CRP) data from USDA FSA was summarized for total acres under CRP contract in each county on September 1, 2000. Acres of active CRP grass and active CRP tree contracts as of September 15, 2000 were summarized and compared by county. These acres were compared to total acres of grass, tree and wetland acres from the CSRA sheets. Because the total acres of grass, tree and wetland acres reported on CSRA sheets should include all CRP lands in addition to other land use changes such as addition of grassed waterways, buffers, windbreaks and other conservation practices. We expected the CSRA values to be at least as high as the CRP values. We discussed inconsistencies with Nebraska, and modified some CSRA sheets as needed.

This spreadsheet summarized acres of total cropland that is planted in different crops according to CSRA forms. These acres were compared to acres of cropland harvested in corn, soybeans, oat, wheat, milo and hay from NASS. We expected these areas to be relatively close together. When significant differences were noted, the data was discussed with Nebraska. A few crop rotations were adjusted in some CSRA forms.

Acres harvested and yield of corn, soybeans and small grain, from NASS, were summarized by county, by year and by tillage system. Acres of crops grown under various tillage systems from CTIC were summarized by county by year. CSRA data was included. These three databases were combined into one spreadsheet such that several graphs could be easily displayed. Selecting any Nebraska county from a pull down menu would display four separate graphs.

The most valuable graph displayed total acres of cropland from CTIC, acres of crop & fallow & forage from CTIC, acres of fallow from CTIC, acres of No-Till from CTIC, acres of cropland with >15% residue from CTIC, total acres of No-Till cropland from CSRA, total acres of Moderate-Till cropland from CSRA and total acres of cropland from GAP in 1993. This data was graphed over time from 1985 through 2000 and the cropping and tillage differences are illustrated in the Dakota and Cheyenne examples (Figure 29 and 30).

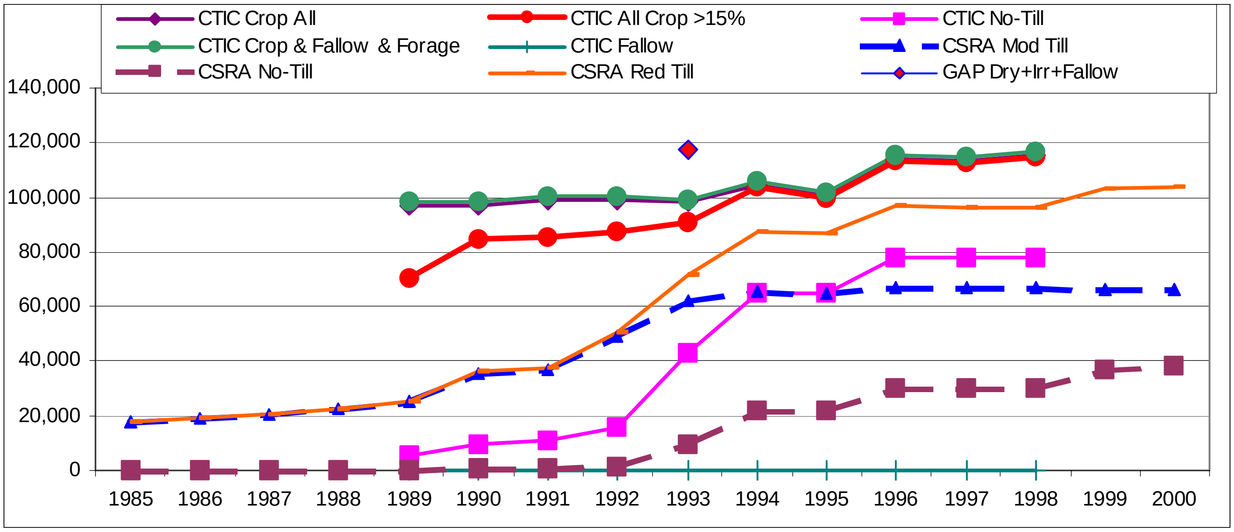


Figure 29: Dakota County tillage data

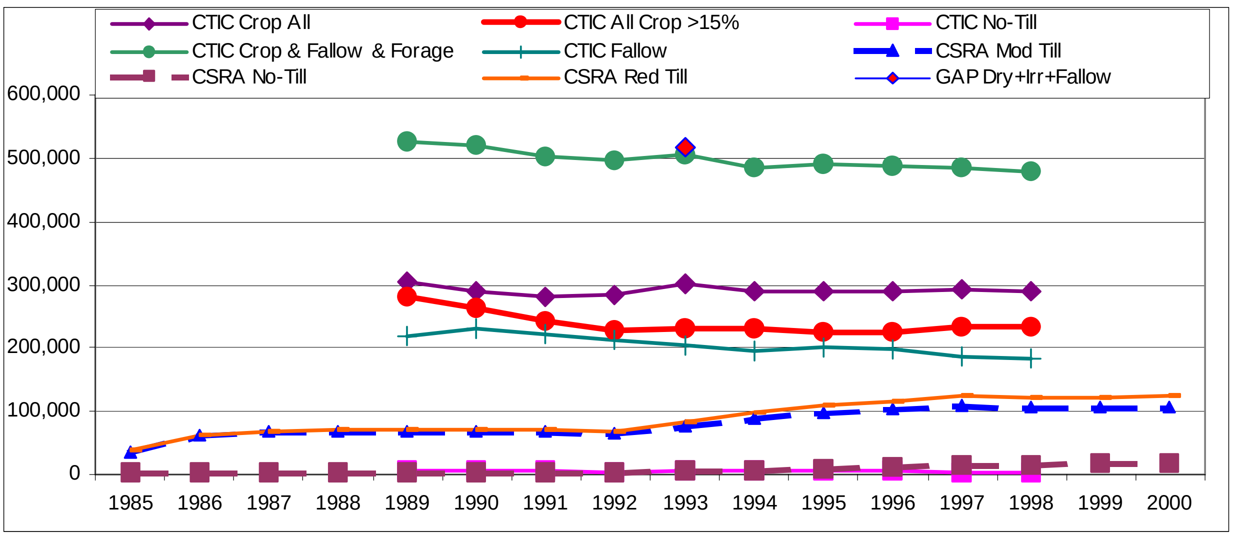


Figure 30: Cheyenne County tillage data

A second important graph displayed total acres of corn, soybeans, small grains, fallow, forage, pasture and milo from CTIC data from 1989 through 1998. Acres reported on CSRA sheets were plotted as a dot in 2000 for comparison. Again, Figure 31 illustrates crops being grown in eastern Nebraska being dominated by corn and soybeans and Figure 32 illustrates crops being grown in Western Nebraska where wheat-fallow is a common rotation.

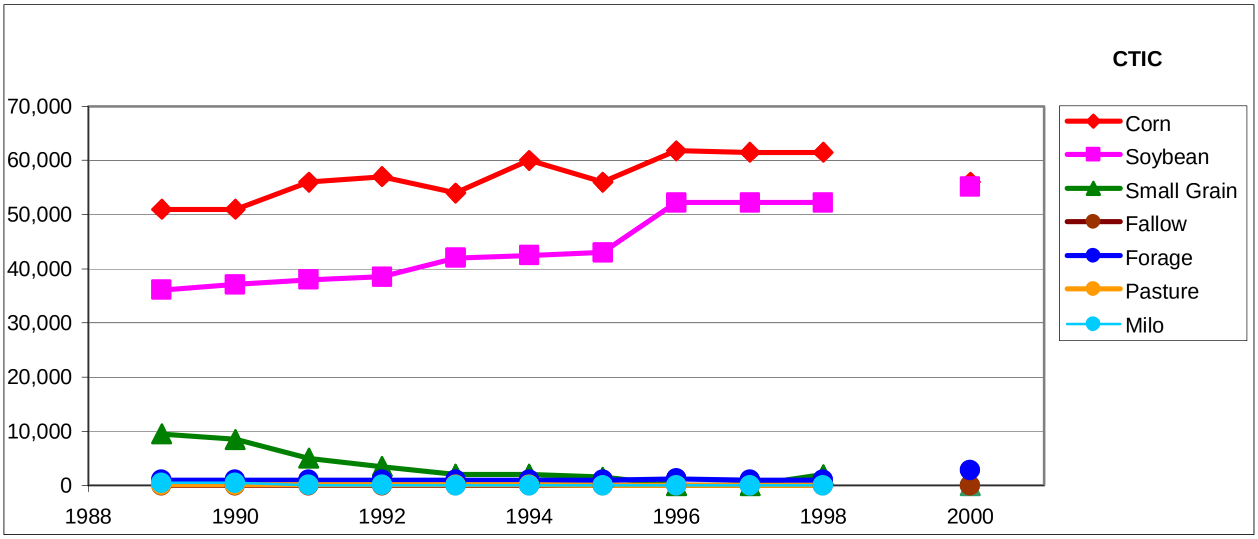


Figure 31: Dakota County crop acres from CTIC data

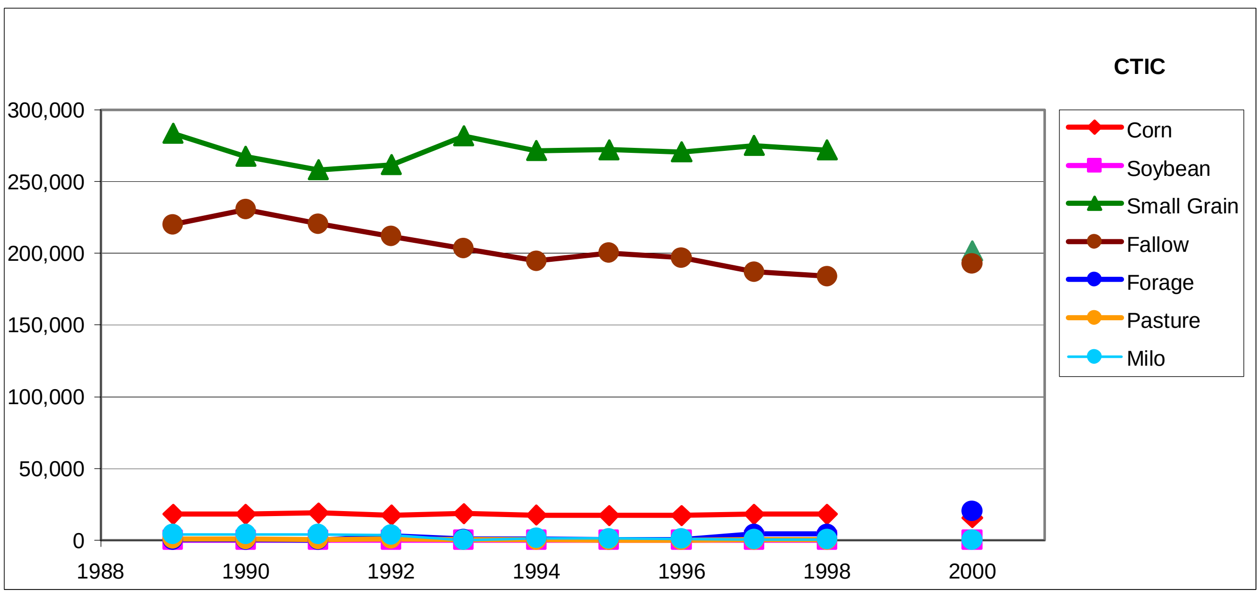


Figure 32: Cheyenne County crop acres from CTIC data

Other graphs displayed acres of corn, soybean, small grain and milo being grown and the associated tillage from CTIC. This provided a review to check the local land managers estimate the extent of intensive, moderate and no tillage occurring within their counties. Figure 33 shows that no tillage has increased from 4050 hectare (~10,000 acres) in 1991 to over 17,500 hectare (~43,000 acres) in 1998 in Dakota County. This large expansion of no tillage is also evident in soybeans and supported by the local land managers when completing the CSRA (Figure 29). Figure 34 details that there has been little change in tillage over the last 10 years in Cheyenne County with three fourths of the land growing small grains having 15-30% which we attribute to moderate tillage systems, but the local land managers only reported 42,900 hectare (~106,000 acres) of moderate tillage (Figure 30). It also shows that very little no tillage is occurring and this is supported by the CSRA.

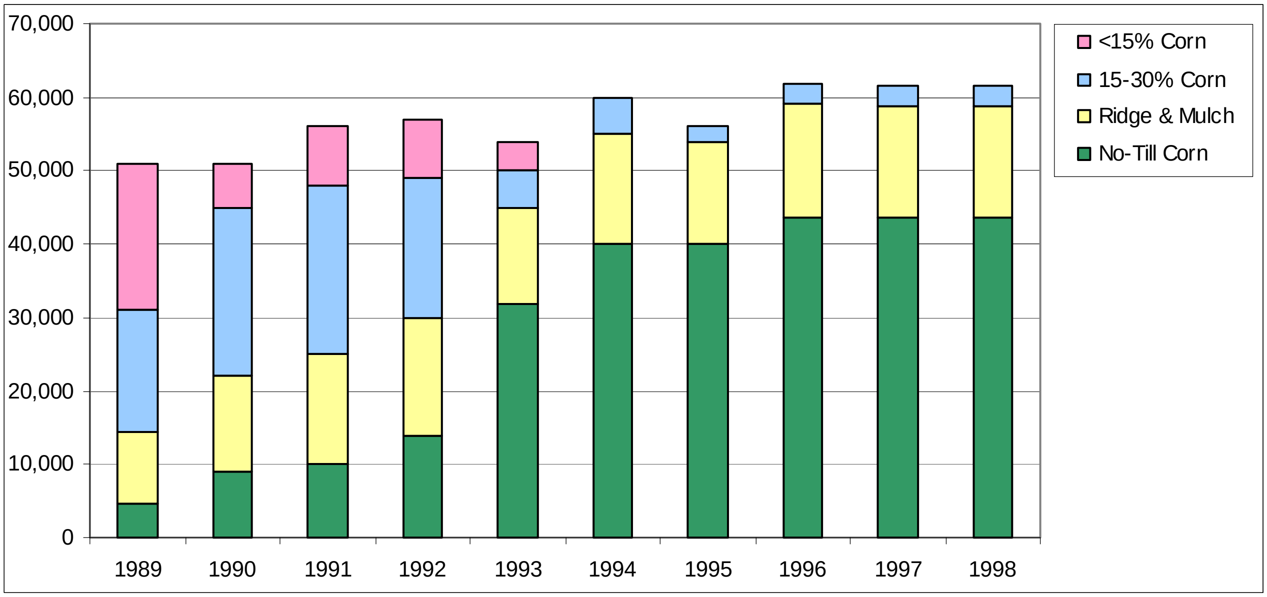


Figure 33: Dakota County corn acres by tillage system from CTIC data

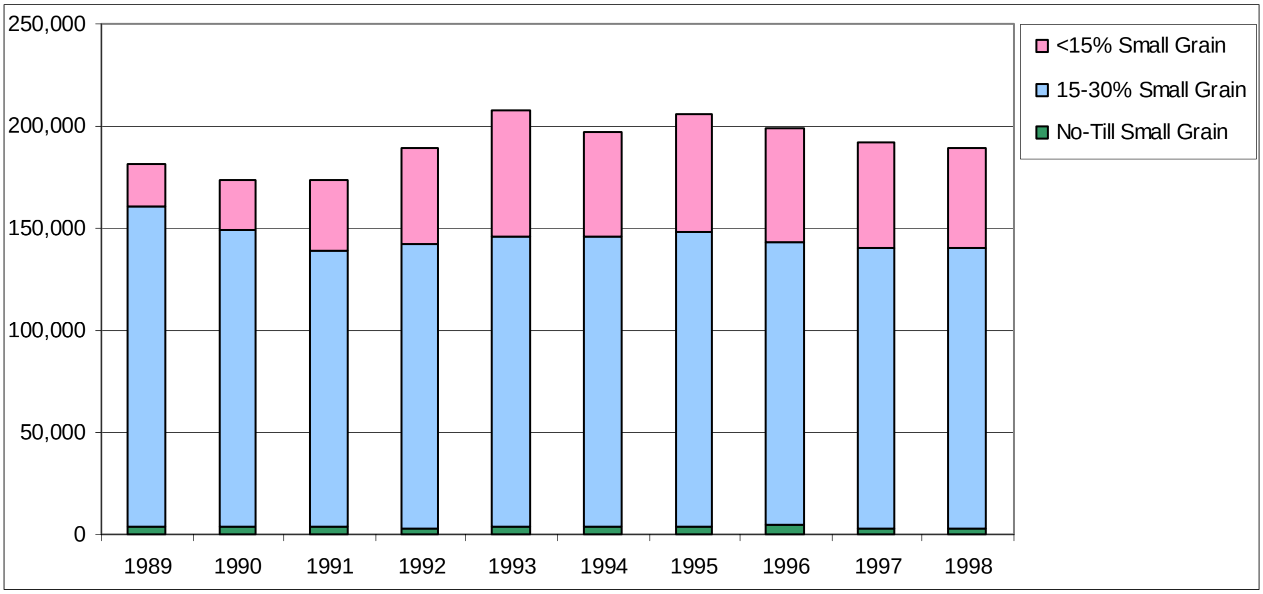


Figure 34: Cheyenne County small grain acres by tillage system from CTIC data

Definitions used by CTIC and CSRA are somewhat different for what lands are considered no tillage or moderate tillage. An example of moderate tillage in the CSRA is a corn-soybean crop system where the land manager is tilling the corn year and using no tillage in the soybean year. In contrast, CTIC would identify the soybean year as having a no tillage system. Due to these real differences in definitions between CTIC and CSRA and in differences in data collection, we did not expect the graphs would look identical, but we did expect some similarities and trends. When these expectations were not met, we discussed the data with Nebraska. In some instances, we modified CSRA data to more closely approximate data from other sources. In other instances, we believed the CSRA data to be appropriate, even though it didn't always approximate data from these other sources.

CSRA Relational Database

A relational database was developed to manage the data provided by the various Nebraska counties for the county level assessments. This database was necessary to define the relationships between the various crops, non-irrigated and irrigated rotations, tillage operations, and cropping histories. Data had to be organized from the spreadsheets into a set of standard query language (SQL) strings in order to insert the data into the relational database. The result was a straightforward and highly adaptable relational database structure that improved the efficiency of the model runs. The various tillage events then had to be organized into tillage sequences that the Century model could interpret appropriately. The data were then fed directly from the database to a series of PERL computer scripts that built the schedule files necessary to run the Century model for the various combinations of crop histories, soils types, non-irrigated and irrigated rotations and hydric conditions. Developing the database and moving the data between the data entry spreadsheets to the database took a substantial amount of effort. Quality control of the CSRA data was necessary to provide consistent terminology, definitions, and units between counties. The final data set was the end result of dozens of sets of modeling runs, each set consisted of tens of thousands separate CENTURY simulations. Each of the interim model runs that was done prior to the final result led to new discoveries about the data set, requiring minor modifications and corrections to the input data. Having the input data in a relational database substantially eased the process of doing the model reruns.

Century Modeling and Analysis

Initial model parameters were set according to the procedure outlined in the Century Model Description section of this report. The equilibrium Century runs provide the initial soil organic matter levels in the different pools. The model then simulated changes in soil C as a function of past agricultural practices based on dominant crop rotations and management practices reported in the CSRA. The onset of cultivation and irrigation occurred at different times throughout the state with some areas beginning prior to 1890 (we started the crop history at 1861), some areas around 1900 and some areas after 1950. For this analysis, non-irrigated cropping histories were divided into periods between 1861-1890, 1891-1920, 1921-1950, 1951-1974, 1975-1994 and 1995-present. If a county did not report a crop history in the pre 1890 time frame, then the corresponding grass condition was used until a crop rotation was reported. Prior to 1950, we only asked for predominate crop rotation in each time period based on the lowland and upland landscape positions. Crop rotations modeled include both non-irrigated and irrigated systems. Prior to 1950, we limited the irrigation option to the lowland landscape to capture the surface irrigated lands along watercourses. Irrigation after 1950 was initiated based on the crop rotation information provided in the CSRA. Irrigation was modeled by assuming that water applied was sufficient to meet full crop demand (i.e., irrigation plus precipitation equaled potential evapotranspiration during the growing season). In areas where rangeland was converted to cropland recently, we assumed these areas as becoming irrigated cropland in 1975 and modeled all the irrigated rotations within the county as identified in the CSRA. Crop production potentials were also varied over time to mimic long-term changes in crop yields as reported by NASS, with yields increasing by 1-2% per year since the 1950s. For each time period, the local experts completing the CSRA specified the crop rotations and management practices (i.e., tillage, fertilization, manuring) that were representative for their area.

Soil driving variables were developed as described in the Phase I section of this report. Drainage dates were provided by the CSRA for each county. The hydric soils were drained in two phases as reported in the CSRA (Appendix C). Only non-irrigated crop rotations were run on hydric soils.

Century simulations were run based for all the combinations of unique histories including the non-irrigated and irrigated crop rotations. These runs provided a typical scenario for each county. Based on the tillage definitions in Phase I of this report, intensive, moderate and no tillage systems were run for all crop rotations as described in the relational database. To simulate changes due to the Conservation Reserve Program (CRP), all the crop rotations, under intensive tillage, were modeled with a change to CRP grass plantings for a ten-year period, starting in 1985. Two different CRP grass plantings were modeled for each non irrigated crop rotation. One CRP planting contained 25% legume and 75% grass in the mixture. The other planting contains 100% grass planting. Staring in 1995, all of these options were continued for an additional 20 years, along with all combinations of changes between crop rotations, CRP, and tillage regimes.

To address the impact of grazing on natural grasslands, we provided an analysis for all soil types in each county based on three levels of grazing intensity (light, moderate and heavy) during the growing season as described in Century. The three grazing intensities were modeled for 20 years and then continued for an additional 20 years. We also allowed each grazing event from the first 20 years to go into each of the other options in the second 20 years. This allows for the analysis of the impact grazing management on soil C and also provides a method to estimate the C sequestration potential based on the CSRA range condition data provided by local land managers and is described in the Phase II Results Section.

This provided approximately one million modeled combinations of average county climates, soil types, and management sequences for the state. The results, available in the COMET database, provide the rate of soil C change for each of these management combinations and associated conservation practices.

Detailed analysis of these rates showed that Century initially overestimated corn grain yields when compared to NASS county averages and C inputs by over 30% for several of the southeastern counties. Further analysis of these southern counties reveled that conservation practices were being utilized to address soil erosion and soil slope issues. We also looked at the hydrology in this area and based on USGS hydrology values for runoff, this area is on of the highest in the state. Based on this, we reduced the Century soil layers from 6 layers to 4 layers for 10 counties in the southeast part of the state and rerun all the simulations. These new runs show that Century is estimating slightly over current NASS averages across the state. We feel that the Century yield estimates reflect additional C inputs into the system which are not reflected in harvested datasets, such as harvest losses (Hanna and Van Fossen, 1990; NDSU, 1997), insect damage and severe weather events (i.e. hail, flooding, ect).

Additional information was compiled from the literature to estimate net soil carbon changes for minor land use practices that were not modeled by Century, including changes associated with tree conversion and wetland restoration on former cropped land and cultivation of organic soils. Mean rates of carbon change (on a per hectare basis) for cropland conversion to trees were taken from Lal et al. (1998). The rates for cropland conversions to wetlands were taken from Armentano and Verhoeven (1990). CSRA provides the area associated with the tree conversion and wetland reversion conversion practices.

Phase II: Results

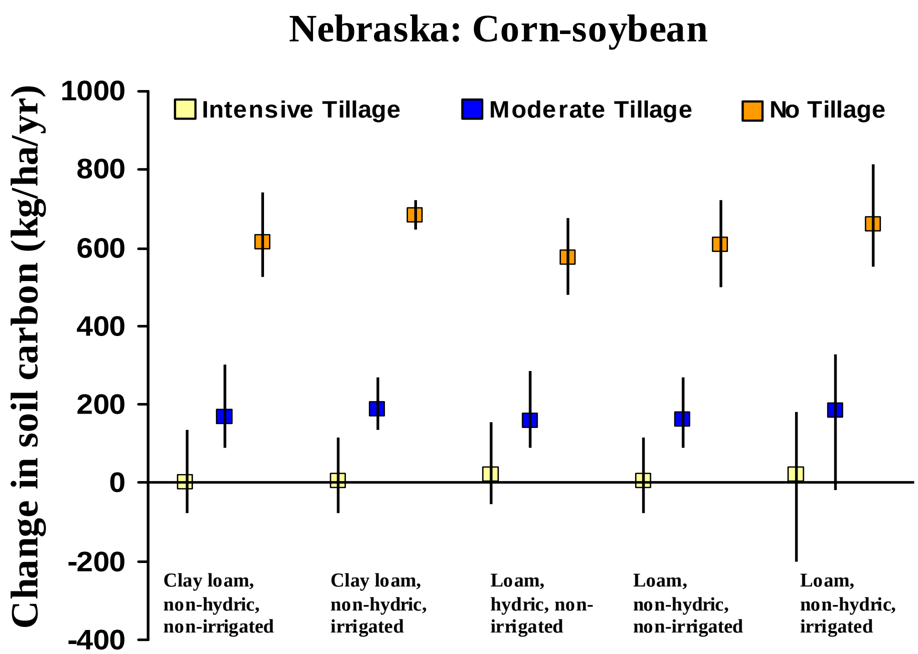
State Summaries

The principle management trends affecting simulated soil C stock changes for the state of Nebraska were the increase in the adoption of moderate tillage and no tillage systems, the reduction of fallow and the introduction of the CRP. In addition, there is a general long-term trend of increasing crop residue inputs, associated with productivity gains (on the order of 1-1.5% per year) since the 1950s (Reilly and Fuglie, 1998), which contributes to increasing soil C stocks in the annual crop systems, even for some intensively tilled soils.

No tillage and moderate tillage systems have increased in Nebraska from 1% and 44% of total annual cropland in 1990 to 5% and 52% in 2000, respectively. No tillage and moderate tillage systems in non-irrigated cropland represent 6% and 45%, respectively in 2000. No tillage and moderate tillage systems in irrigated cropland represent 3% and 62%, respectively in 2000. It should also be noted that irrigated cropland accounts for 38% of the cultivated land in 2000.

Mean rates of soil C change for non irrigated and irrigated corn-soybean rotations for all tillage options on loam and clay loam soils and non irrigated wheat-fallow rotations on loam soils are shown in Figure 35. Rates are state averages over the period 1994-2004 and are based on the same rotations over the period 1975-1994. Bars within columns show the range of values across all counties reflecting past crop history and climatic differences in the state. Rates for moderate tillage and no tillage are averages for a ten-year period following conversion from intensive tillage. Also shown are projected rates of change with continuation of intensive tillage practices. No tillage is sequestering the highest rates of C followed by moderate tillage systems. Intensive tillage systems can be sequestering low rates of C or even losing C to the atmosphere. Irrigation provides slightly higher rates of C sequestration than non irrigated crop production growing corn-soybeans across all tillage systems. The model is showing the wheat-fallow intensive tillage systems at equilibrium or still losing C in the western part of the state under intensive tillage. When these systems are converted to moderate tillage or no tillage, the soils start to sequester C but at low rates.

In summary, estimates of the current rates of C change under the predominant crop rotation in Nebraska are due largely to changes in tillage practices, but with an underlying influence of increasing crop residue inputs for all systems.



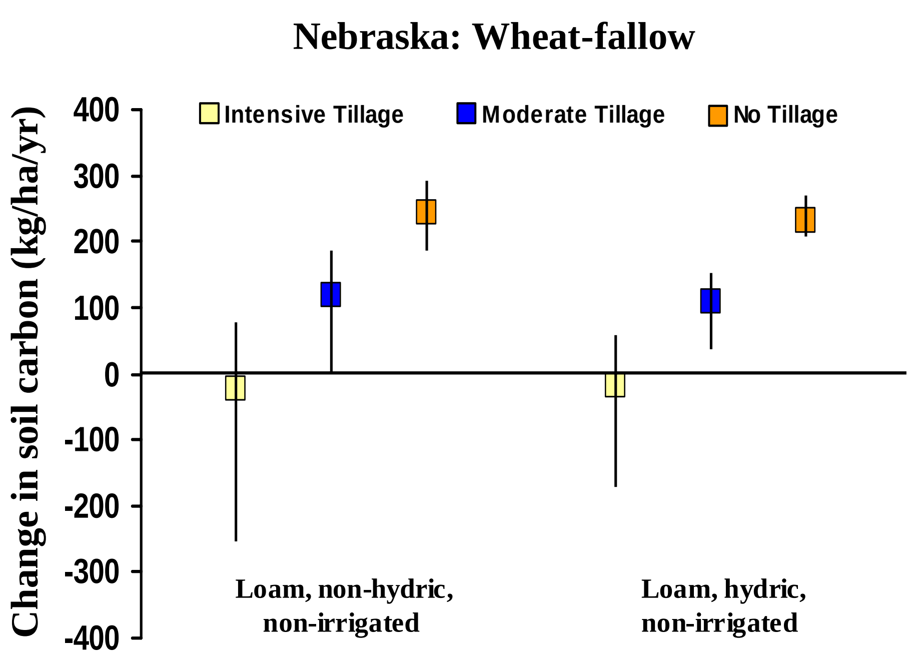


Figure 35: Changes in soil C across Nebraska

Cropland was estimated to yield 1990 C sequestration rates of about 0.17 tonnes ha^{-1} yr^{-1} (0.08 tons ac^{-1} yr^{-1}) and 2000 C sequestration rates of 0.15 tonnes ha^{-1} yr^{-1} (0.07 tons ac^{-1} yr^{-1}) averaged across the state. This is misleading through due to the different climatic effects and the influence of irrigation within the state. Non irrigated cropland provided 37% and 45% while irrigated cropland provides 63% and 55% of the total C change, respectively. Non irrigated cropland in 2000 under intensive, moderate and no tillage systems is sequestering 0.02 tonnes ha^{-1} yr^{-1} (0.01 tons ac^{-1} yr^{-1}), 0.08 tonnes ha^{-1} yr^{-1} (0.04 tons ac^{-1} yr^{-1}) and 0.38 tonnes ha^{-1} yr^{-1} (0.17 tons ac^{-1} yr^{-1}), respectively. This indicates that intensive tillage is near steady state and results indicate that fallow rotations in the western part of the state are still losing C. Irrigated cropland in 2000 under intensive, moderate and no tillage systems is sequestering 0.18 tonnes ha^{-1} yr^{-1} (0.08 tons ac^{-1} yr^{-1}), 0.21 tonnes ha^{-1} yr^{-1} (0.09 tons ac^{-1} yr^{-1}) and 0.63 tonnes ha^{-1} yr^{-1} (0.28 tons ac^{-1} yr^{-1}), respectively.

Carbon sequestration rates predicted for Nebraska soils with adoption of no tillage are in line with results from several long-term studies in the Corn Belt Region (Paustian et al., 2002). Recent regression based estimates of C accumulation under no-till from 15 long-term sites in the Midwest show average annual rates of 0.72 tonnes ha^{-1} (M. Eve, pers. comm.). Numerous other studies of tillage impacts illustrate the general trend of increased C sequestration from reducing or eliminating tillage, although rates vary considerably according to soil, climate, and management variables (Paustian et al., 1997b; West and Marland, 2001). In a few cases, negligible effects of tillage reduction on soil C have also been reported (e.g., Wander et al., 1998). Additional sources of variability in response to tillage changes that can occur at a site-specific level, such as reduced productivity with unsuccessful no-till management, are not captured in the model application at county and state scales.

Conversion of annual cropland to CRP grasslands was estimated to yield 1990 C sequestration rates of about 0.72 tonnes ha^{-1} yr^{-1} (0.32 tons ac^{-1} yr^{-1}) and 2000 C sequestration rates of 0.57 tonnes ha^{-1} yr^{-1} (0.25 tons ac^{-1} yr^{-1}) averaged across the state. In comparison, Follett et al. (2001) estimated rates of C sequestration for 14 sites in the Central US, based on field sampling of paired CRP sites averaging 0.9 tonnes ha^{-1} yr^{-1} (0.40 tons ac^{-1} yr^{-1}). Paustian et al. (2001) document several field studies of attributing increases in soil carbon with prairie restoration and application of CRP on former annual cropland, with values of around 1 tonnes ha^{-1} yr^{-1} (0.45 tons ac^{-1} yr^{-1}) for conditions similar to those in Eastern Nebraska. The model does not reflect the full range of variability in C change under CRP that would be expected through site-specific effects (e.g., poor stand establishment, high residual nutrient levels, pest effects), which cannot be captured in a regional assessment. It should also be noted that assumptions regarding nitrogen availability have a significant impact on the predicted response of CRP. For the present simulations, we assume that 40% of the CRP planting included a legume component to help meet demands for nitrogen by the perennial vegetation. The same assumption was used for other grass conversions (e.g. grassed waterways, filter strips). The remaining 60% of CRP plantings were simulated using a pure grass, with no fertilization and minimal pre-CRP residual nitrogen.

To estimate current changes in soil C storage under present management systems, we used the mean annual rates of C change for the simulated period for each management sequence X soil X county combination, multiplied by the area represented by that combination. Compiling all of the model-based estimates for managed cropland and grass with separate calculations for tree conversion and wetland restoration, we estimate that Nebraska soils are currently (i.e., based on 1990 and 2000 data) a net sink for CO_2, accumulating soil C at a rate of about 1.50 and 1.28 MMT per year, respectively (Table 5 and 6).

Table 5: 1990 summary of C sequestered by management system in Nebraska

Management System	Metric Units			English Units		
	Hectare	Tonne C	Tonne CO_2	Acre	Ton C	Ton CO_2
Cropland	8,216,496	1,195,391	4,387,085	20,303,323	1,317,679	4,835,882
CRP/Grass Conv.	427,977	307,086	1,127,006	1,057,550	338,501	1,242,299
Tree/Wetland Conv.	3,985	2,083	7,645	9,847	2,296	8,426
State Total	8,648,458	1,504,560	5,521,736	21,370,720	1,658,476	6,086,607

Table 6: 2000 summary of C sequestered by management system in Nebraska

Management System	Metric Units			English Units		
	Hectare	Tonne C	Tonne CO_2	Acre	Ton C	Ton CO_2
Cropland	8,196,325	1,028,351	3,774,048	20,253,480	1,133,551	4,160,132
CRP/Grass Conv.	436,396	246,576	904,934	1,078,354	271,801	997,510
Tree/Wetland Conv.	15,756	8,173	29,995	38,934	9,009	33,063
State Total	8,648,477	1,283,100	4,708,977	21,370,768	1,414,361	5,190,705

The largest contributions to this C sequestration is attributed to the large area of irrigated cropland in the state and the reduction of areas under intensive tillage over the past 10 years (Table 7 and 8), and the conversion of formerly annually cropped area to perennial grasses through the CRP, as well as the increased installation of grass waterways, field buffers, filter strips, terrace walls and other conversion to grassed conservation practices (Table 5 and 6).

Table 7: 1990 total C sequestered in mineral soils by tillage system in Nebraska

Tillage System	Metric Units			English Units		
	Hectare	Tonne C	Tonne CO_2	Acre	Ton C	Ton CO_2
Intensive Tillage	4,459,809	388,101	1,424,331	11,020,447	427,808	1,570,055
Moderate Tillage	3,647,206	757,147	2,778,729	9,012,458	834,612	3,063,026
No Tillage	109,481	50,143	184,025	270,535	55,273	202,852
State Total	8,216,496	1,195,391	4,387,085	20,303,440	1,317,693	4,835,933

Table 8: 2000 total C sequestered in mineral soils by tillage system in Nebraska

Tillage System	Metric Units			English Units		
	Hectare	Tonne C	Tonne CO_2	Acre	Ton C	Ton CO_2
Intensive Tillage	3,550,655	241,768	887,288	8,773,876	266,503	978,066
Moderate Tillage	4,222,328	588,271	2,158,955	10,433,618	648,458	2,379,841
No Tillage	423,342	198,312	727,805	1,046,102	218,602	802,269
State Total	8,196,325	1,028,351	3,774,048	20,253,596	1,133,563	4,160,176

Of the 8.2 million hectare (~20 million acre) of Nebraska's cropland, 43% is still managed using intensive (i.e. conventional) tillage practices. Our analysis predicts an overall rate of increase of soil C on managed cropland in the state due to increasing amounts of crop residues added to soil over the past three to four decades with higher rates occurring on land managed using moderate and no tillage systems. Others (Cole et al., 1993; Allmaras et al., 2000) have also suggested that the general trends in crop productivity since WWII have changed agricultural soils from being a net C source to a net sink in the US. Tree conversion and wetland restoration is projected to represent a net carbon sink, but the overall effects on the C balance for the state are minor due to the relatively small 15,756 hectare (38,934 acre) of associated area.

State summaries of annual C changes occurring on cropland are available from 1990-2000 in spreadsheet format and details are provided in Appendix D. Figures 36-39 show the associated areas and three different ways of looking at the state totals of the effects of conservation practices on C sequestration. The COMET database provides each county with estimated amounts of C sequestered under various management practices. The database has been tailored to address the specific climate, soils, and current cropland management systems, and allows the user to project changes in soil C due to changes in crop and tillage practices (Appendix E).

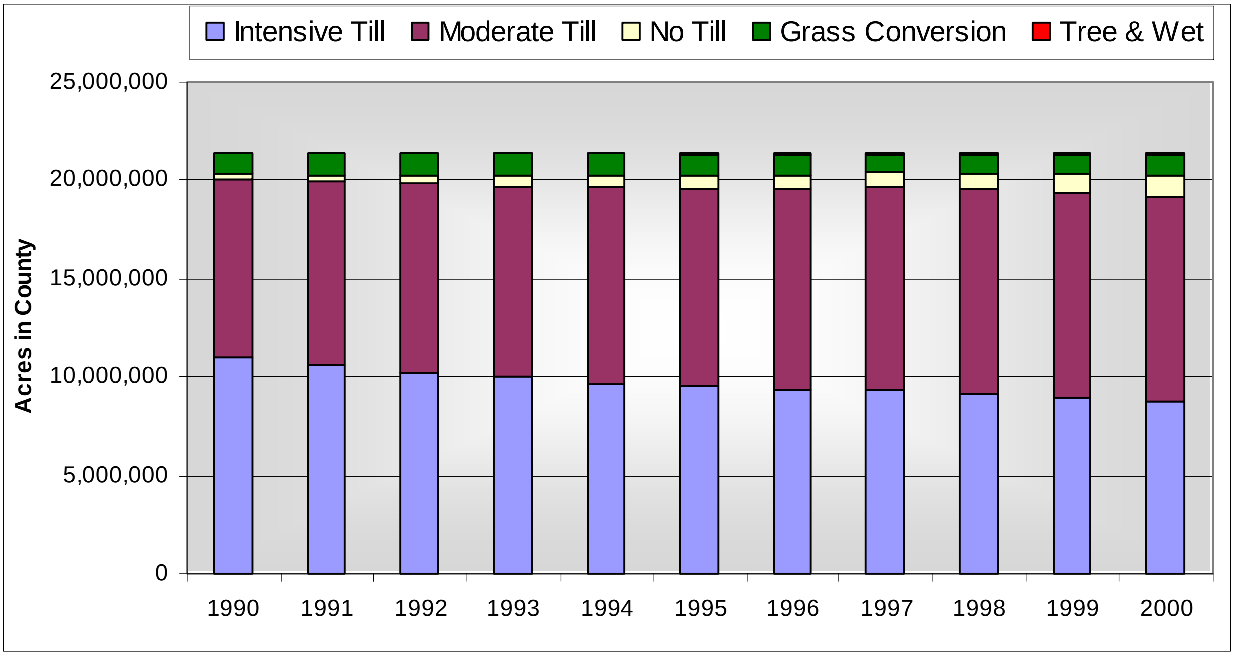


Figure 36: 1990-2000 areas for calculating C change due to conservation practices in Nebraska

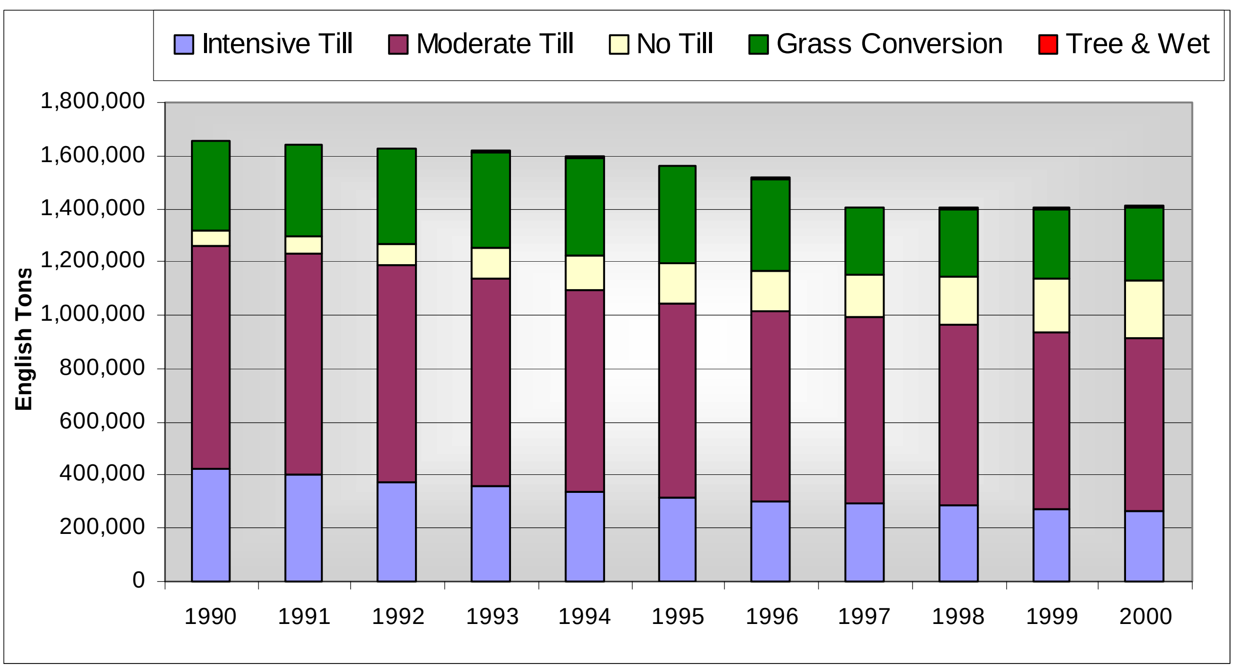


Figure 37: 1990-2000 C sequestration on mineral soils in Nebraska

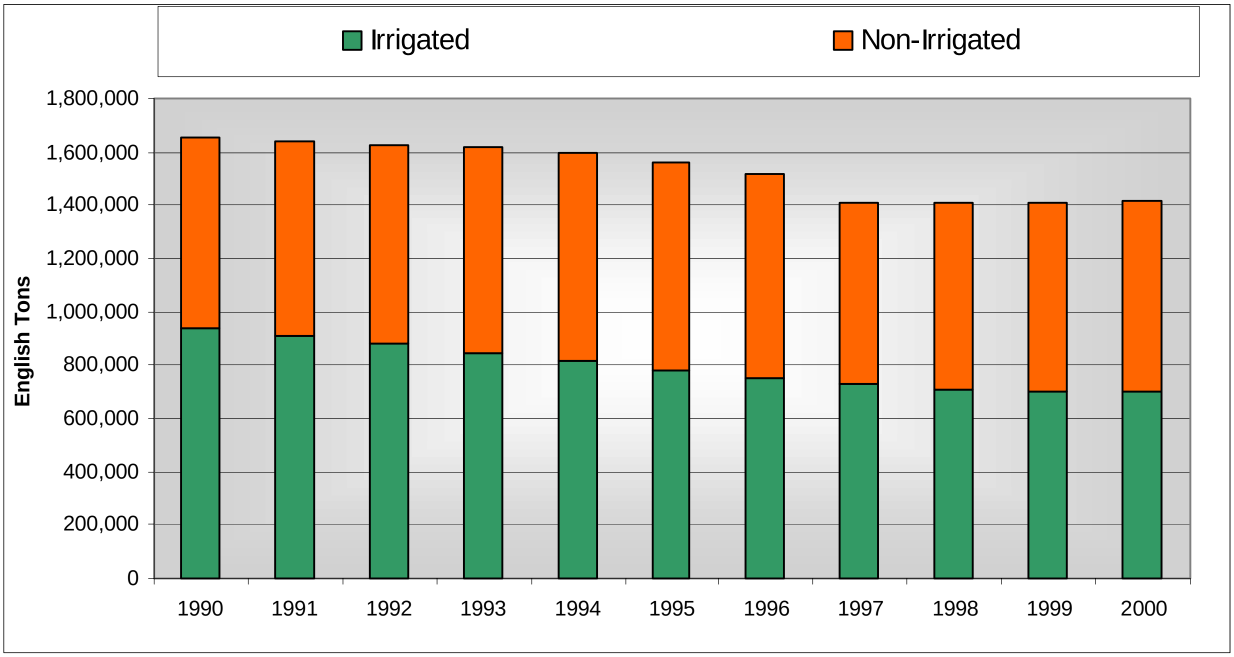


Figure 38: 1990-2000 state totals of C change on non irrigated and irrigated soils in Nebraska

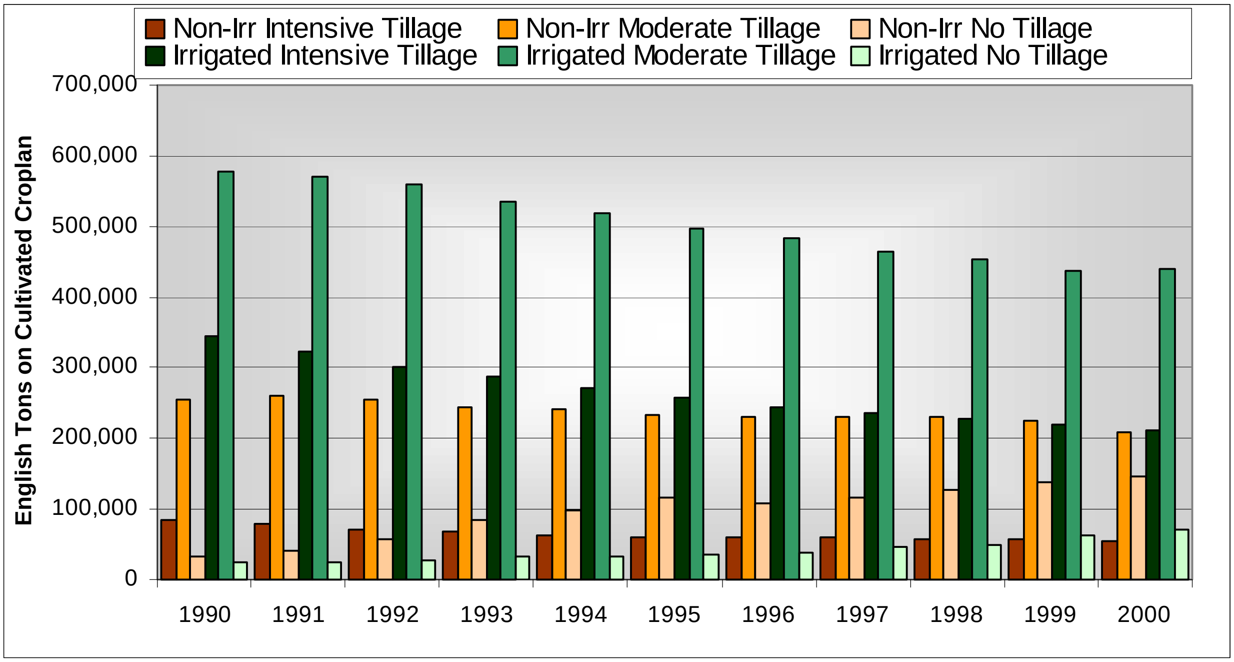
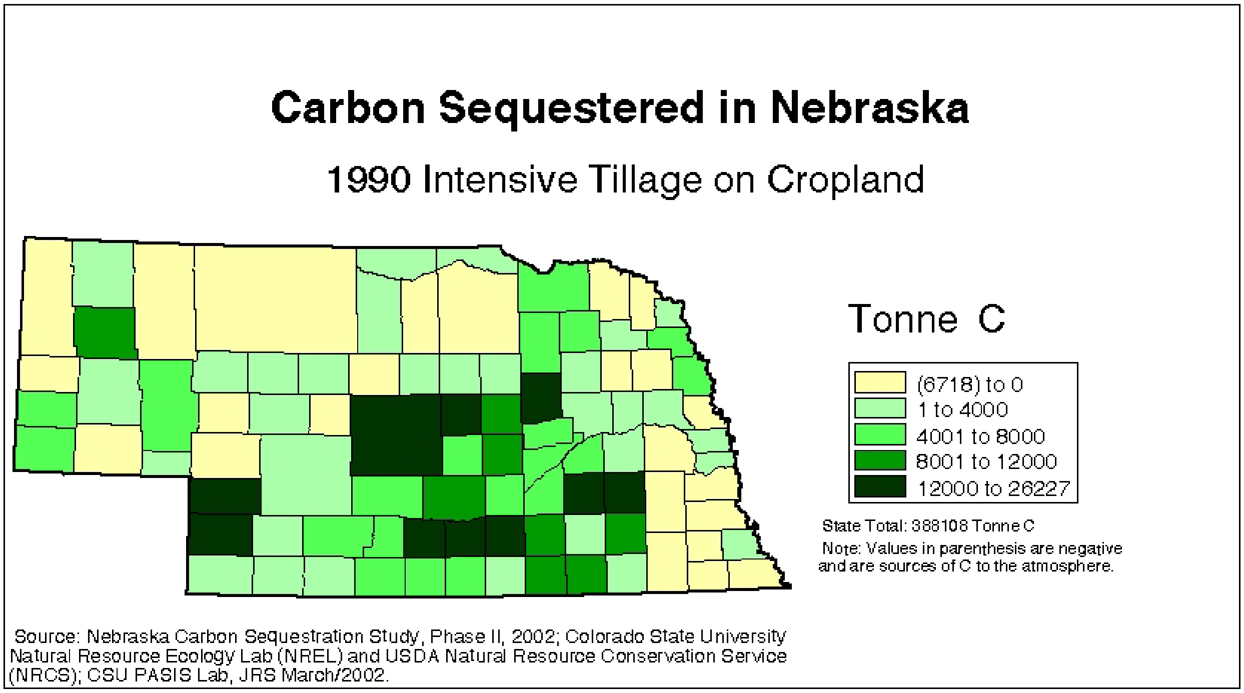


Figure 39: 1990-2000 state totals of C change by tillage class on non irrigated and irrigated soils in Nebraska

County Summaries

The 1990 and 2000 effects of conservation are calculated for the effects on management due to tillage system, CRP, grass conversion, tree conversion and wetland reversion. These effects are summarized in the following figures and are also available for each county on the accompanying CD-ROM. Figures 40-42 show the distribution of the C sequestered in 1990 and 2000 throughout the state for the three types of tillage practices (intensive, moderate and no tillage). Land managers are changing intensive tillage systems to moderate or no tillage systems in most areas, but not all parts of the state. This movement between systems along with the associated C changes over time is showing that Nebraska cropland soils are still providing a significant C sink to the atmosphere. Any effort to move the intensive tillage cropland into moderate tillage or no tillage will have significant effects on the amounts of C that can be sequestered in the soil.

The effects of CRP and grass conservation practices (grass waterways, terraces, grass seeding, etc.) in each county and the associated C being sequestered is based on 60% of the area planted to 100% grass and the remaining 40% utilizing a 25% legume-75% non-legume plant community, which provides a source of nitrogen due to the fixing capacity of legume plants. The CRP lands have been in grass for over 10 years and therefore the rates of C sequestration are declining. The CSRA data provided by the local land manager's detail the amount of additional grass conservation practices (grass waterways, terraces, grass seeding, etc.) that were installed between 1985 and 2000. Since many of these lands have been converted to perennial grass in the last 10 years, the rates of C sequestration are higher, but will decline the longer they are in perennial grass. Figure 43 shows the distribution of C sequestered in 1990 and 2000 due to CRP and grass conversions throughout the state. These lands provide valuable environmental benefits including cover for wildlife, reducing soil erosion and improving water quality. Should the land manager decide to return these lands to crop production, the Nebraska COMET database can provide the effects of different management options to assess the changes in soil organic matter. The database will allow land managers to calculate the projected C sequestration over the next 20 years when these types of practices are installed.



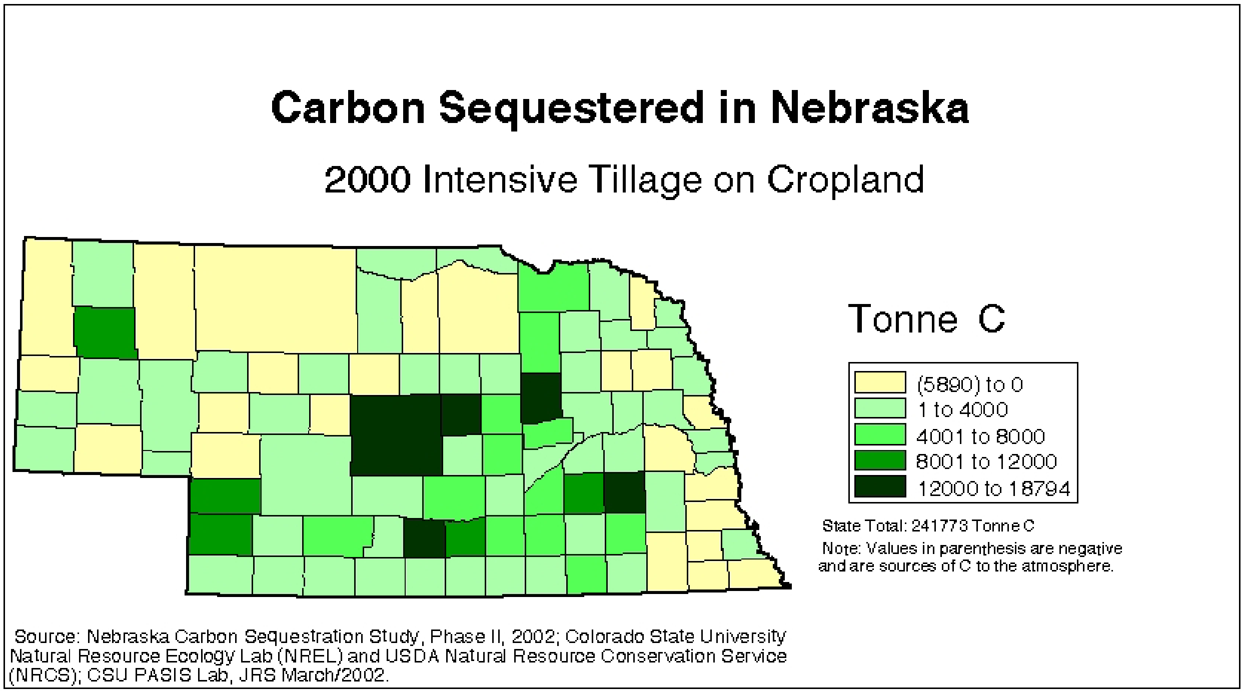
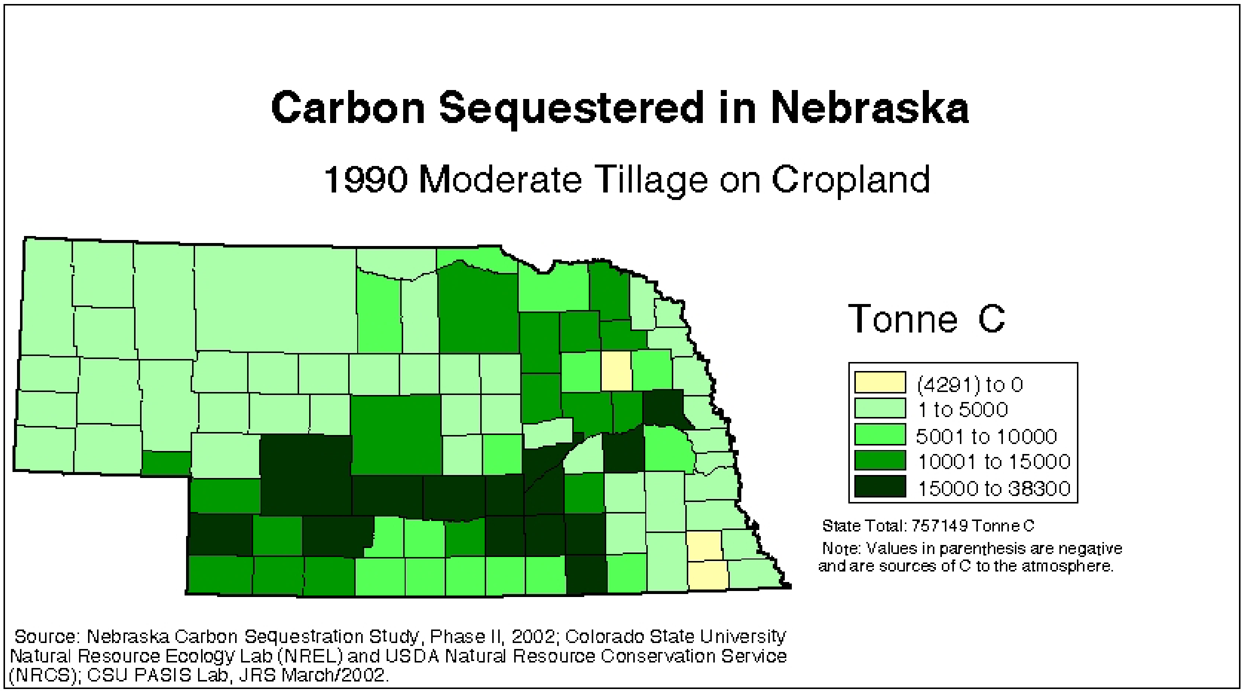


Figure 40: 1990 and 2000 C sequestered on intensive tillage cropland



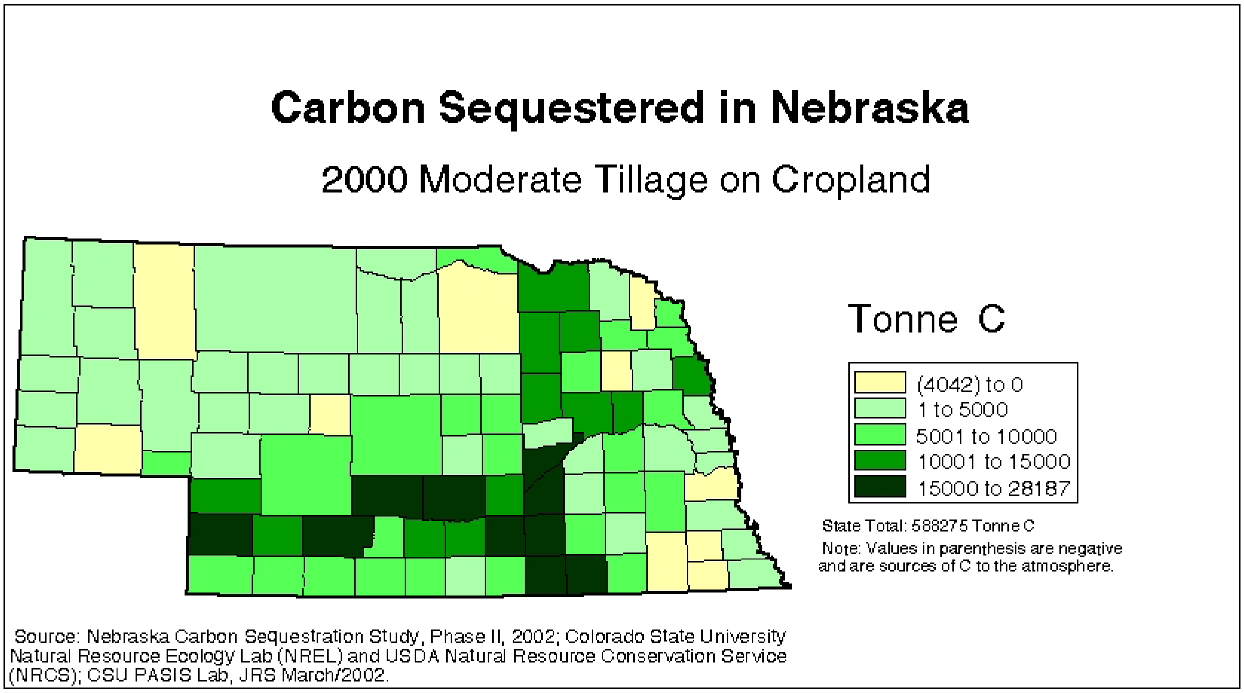
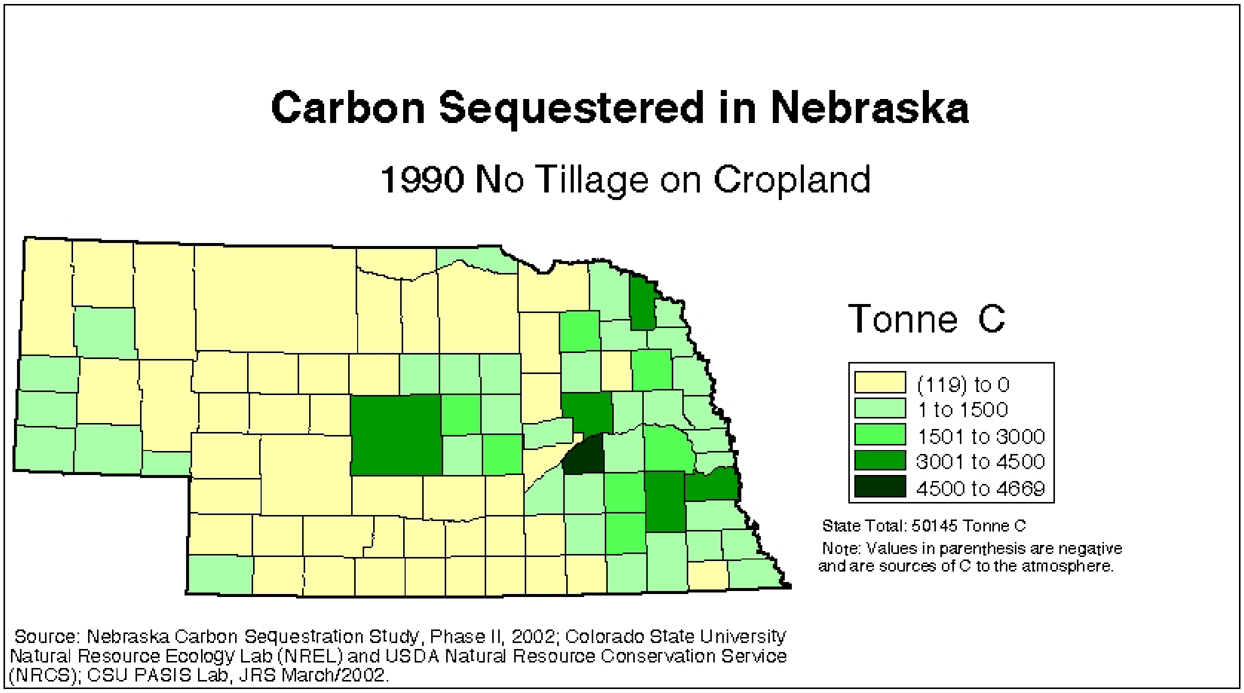


Figure 41: 1990 and 2000 C sequestered on moderate tillage cropland



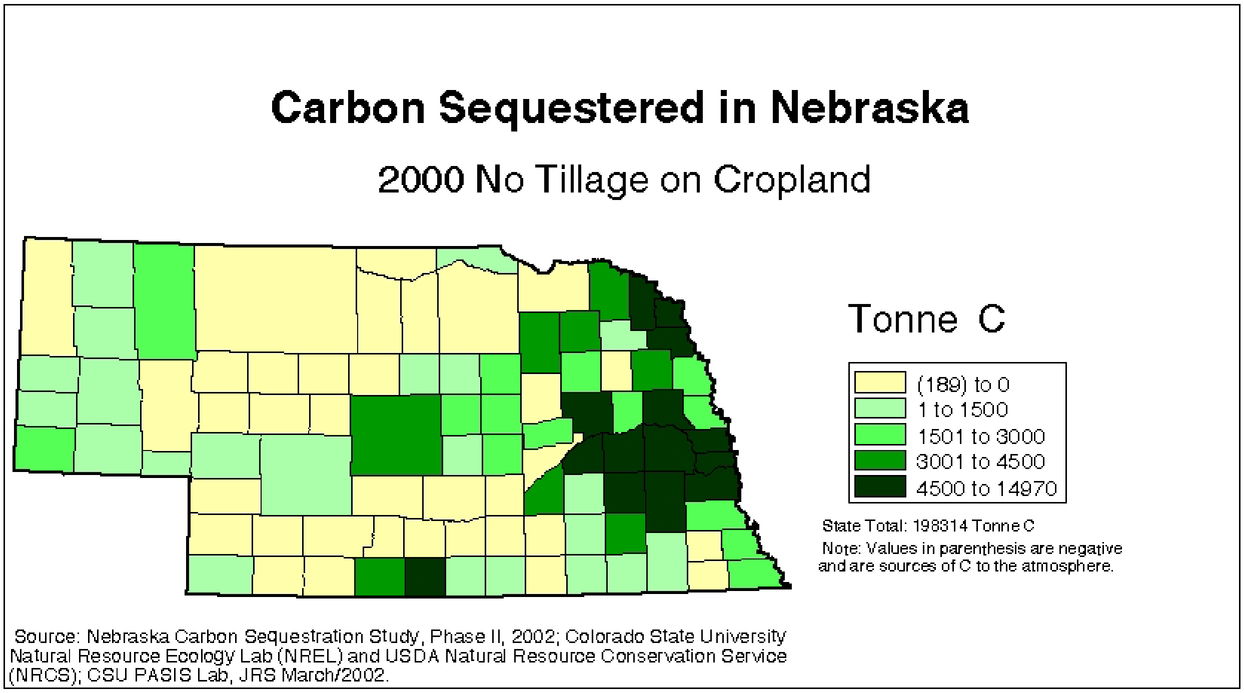
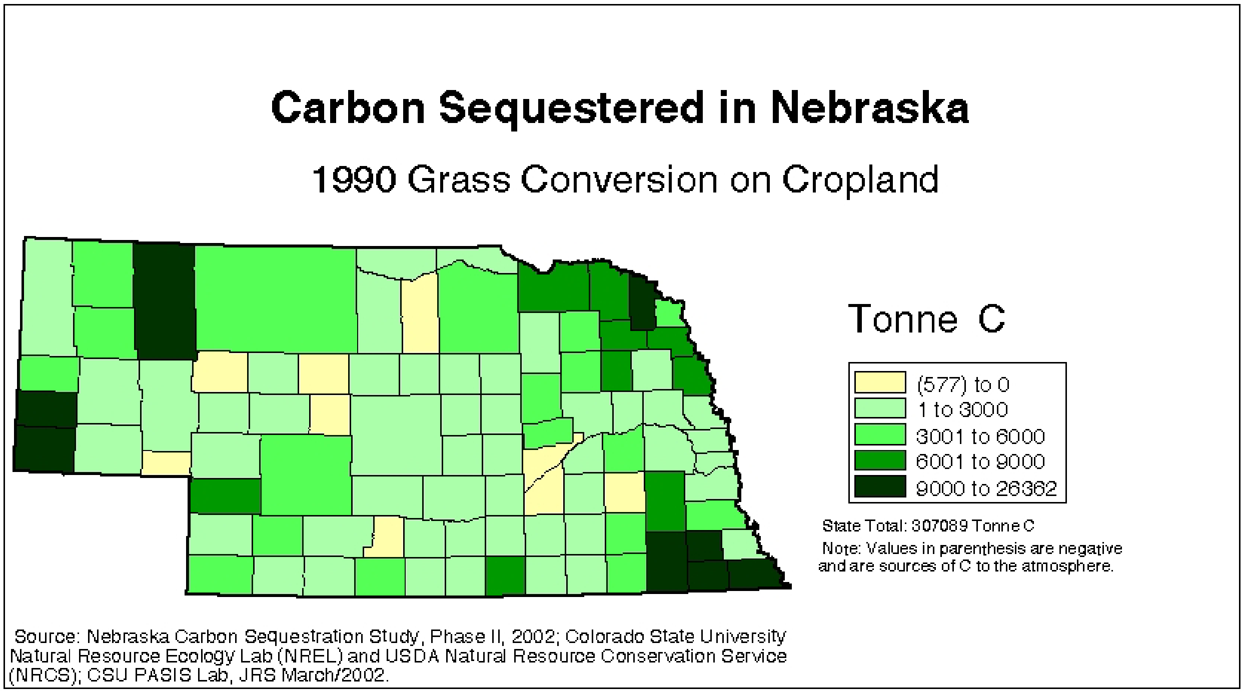


Figure 42: 1990 and 2000 C sequestered on no tillage cropland



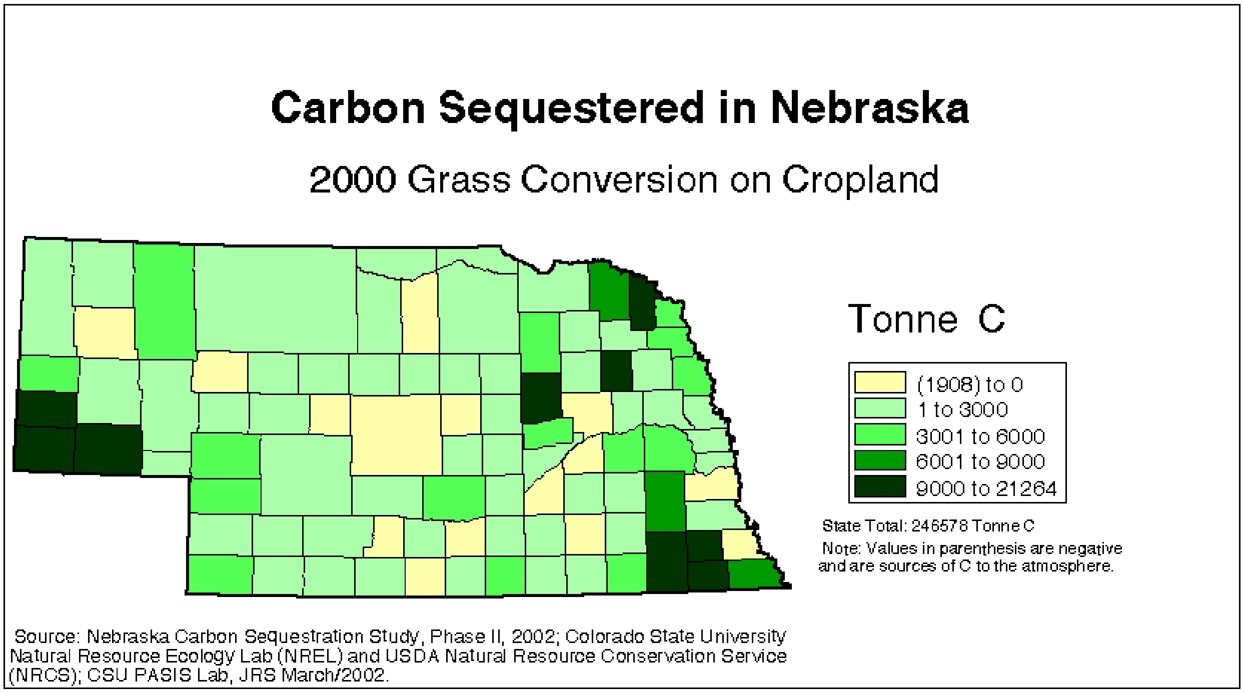
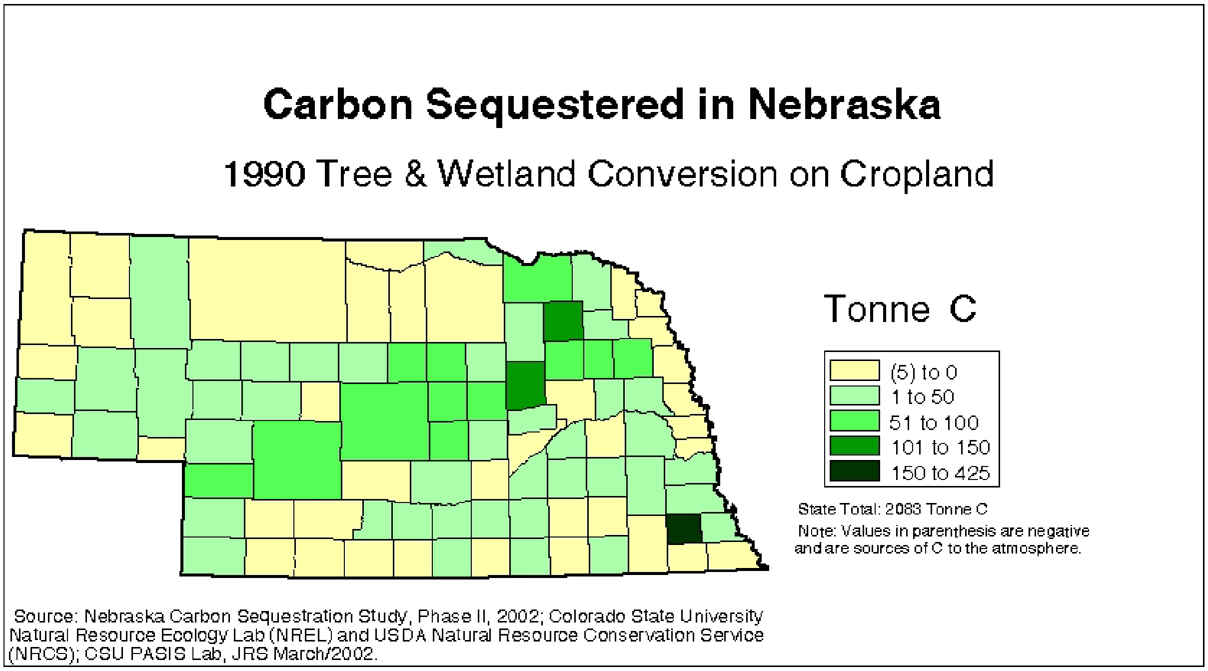


Figure 43: 1990 and 2000 C sequestered on cropland converted to grass

The C sequestration effects associated with tree conversions and wetland reversions are summarized in Figure 44. These small areas need to be identified and accounted for which provides a more complete picture of how C sequestered due to tree conversions and wetland reversions throughout the state. Again, it needs to be noted that these areas do provide valuable cover for wildlife, reduce erosion and improve water quality



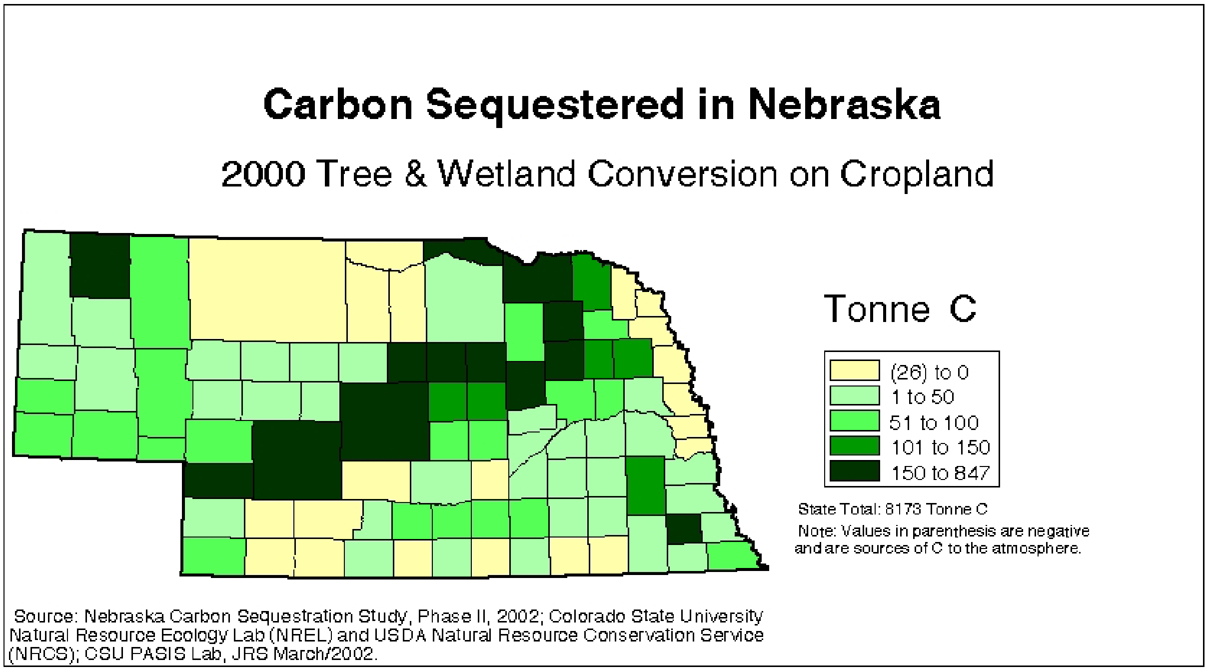
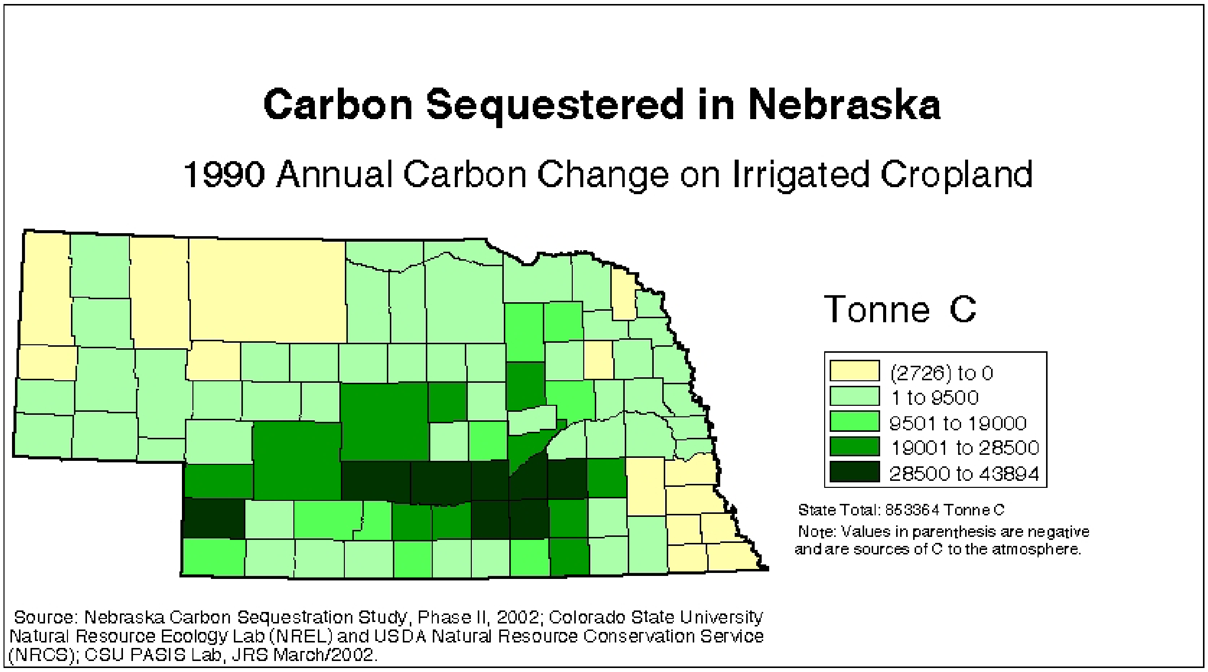


Figure 44: 1990 and 2000 C sequestered with tree conversions and wetland reversions

Figure 45 and 46 shows the areas where C conserving practices are being adapted and the change between 1990 and 2000 on irrigated lands and the total C being requested within each county. Any increase in the amounts of area that utilize moderate or no tillage practices will increase the amounts of C being sequestered.



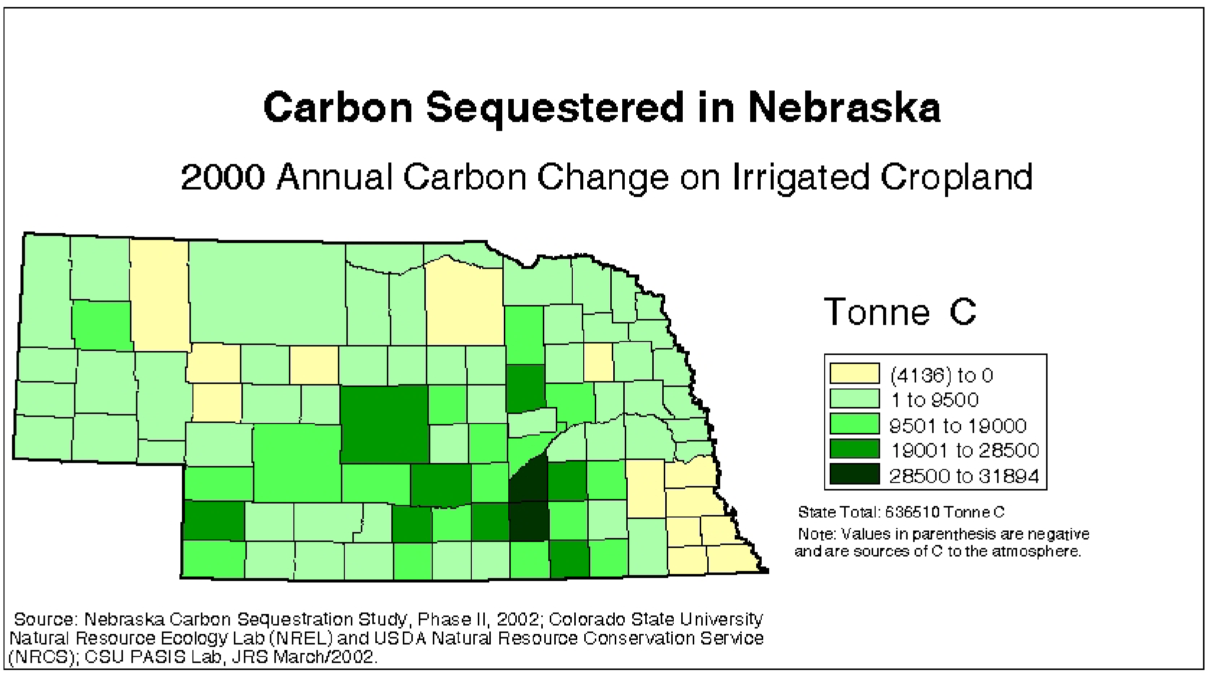
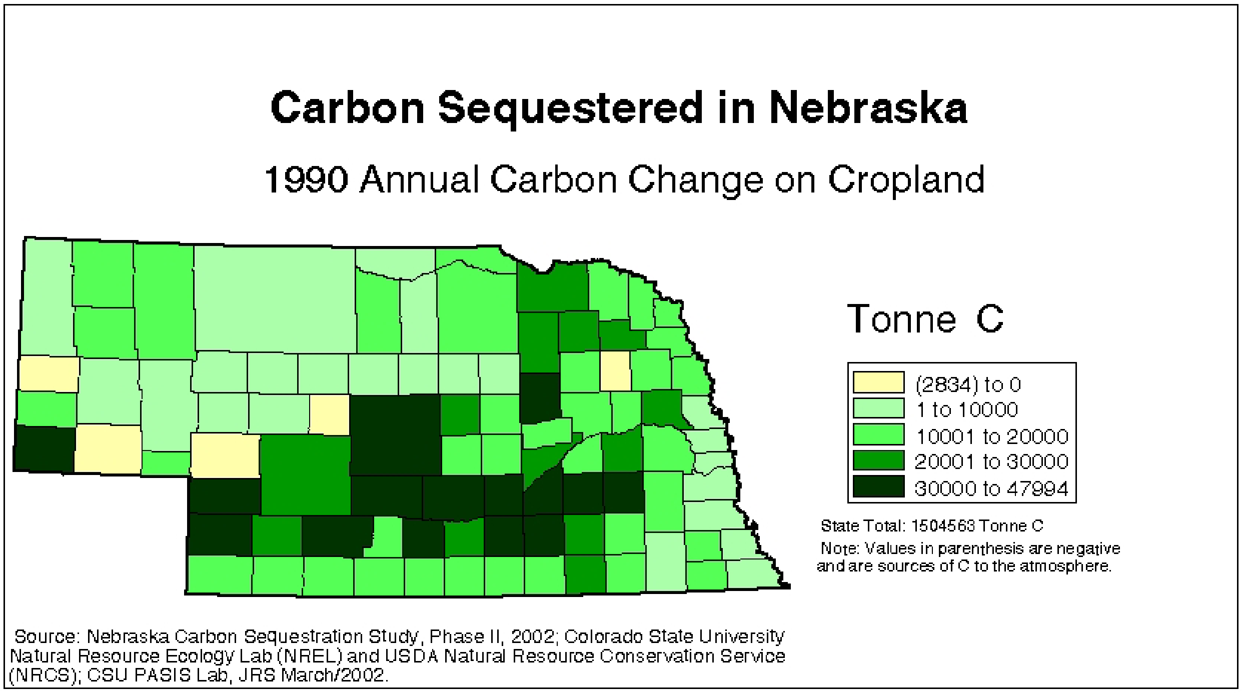


Figure 45: 1990 and 2000 C sequestered in irrigated soils



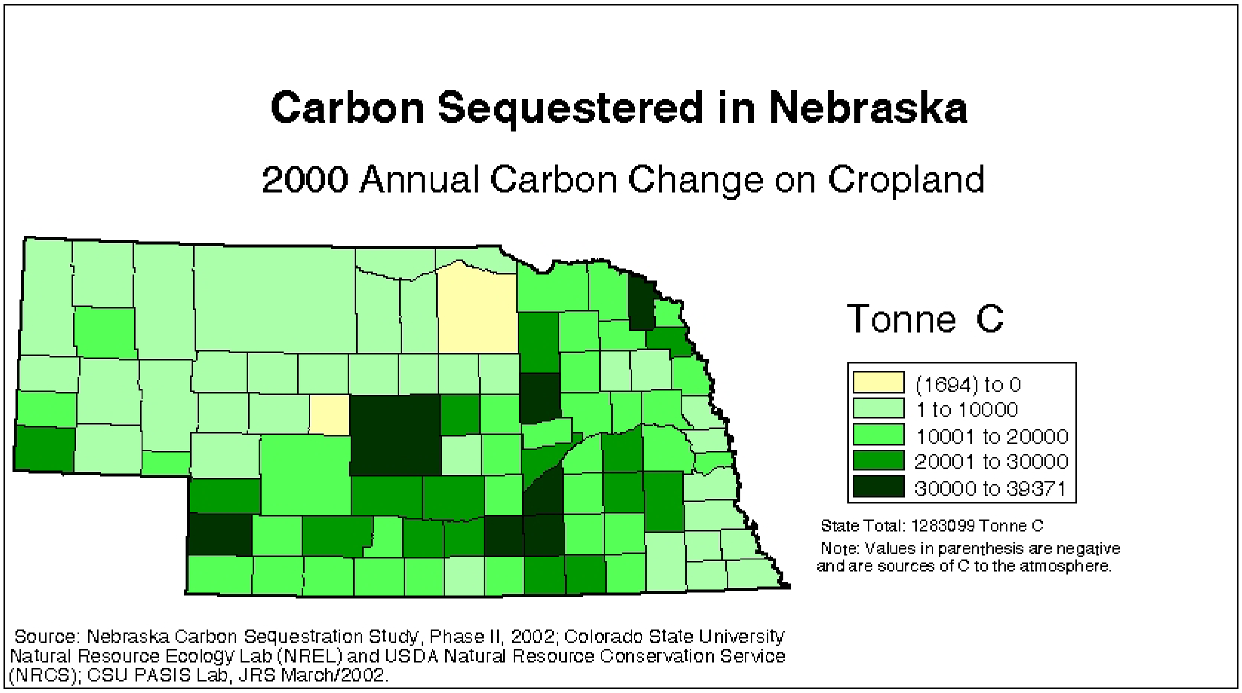
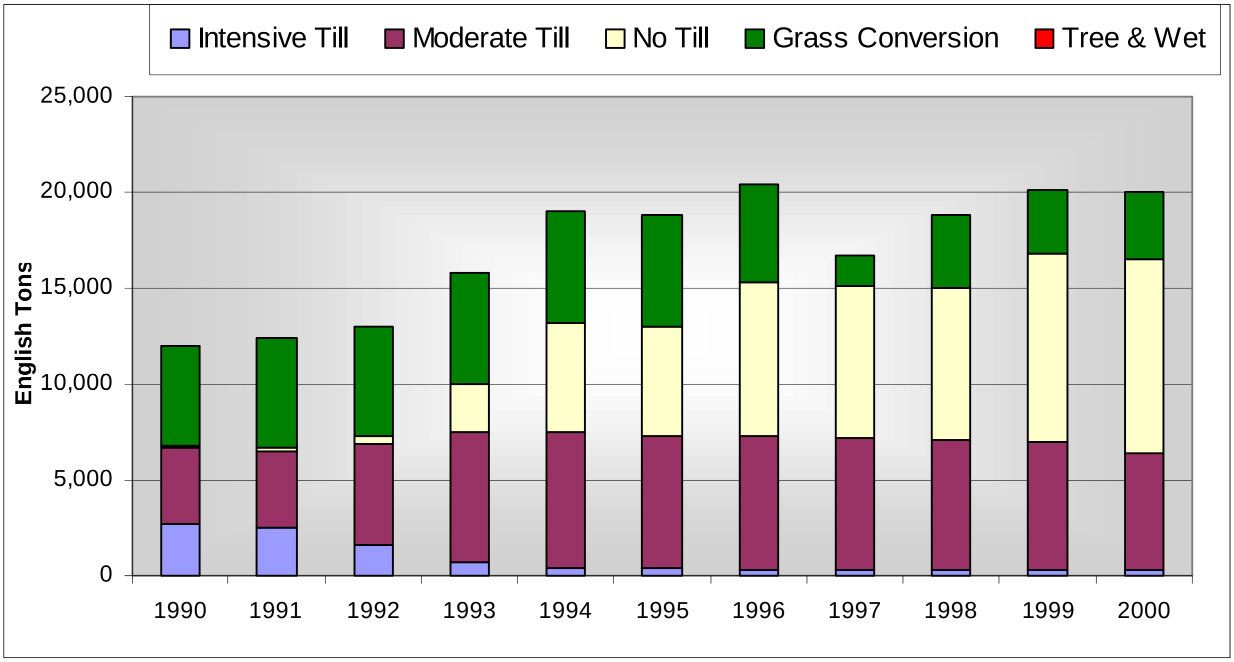


Figure 46: 1990 and 2000 C sequestered in mineral soils

Figure 47-48 illustrates C budgets and the distribution of C being sequestered on various types of tillage systems for two very different counties, one in the eastern part (Dakota County) of the state and another in the western part (Perkins County) of the state. In 2000, Dakota County is sequestering 18,115 tonnes C (19,968 tons C) on 55,232 hectare (136,482 acres) of cropland. Corn-soybean crop rotations dominate with large areas under moderate tillage and no tillage systems. In 1997, over 4,355 hectare (~10,000 acres) of CRP land was converted back to cropland as reported in the CSRA. Then in 1998, over 3,600 hectare (~9000 acres) of land was planted back to grass. In 2000, Perkins County is sequestering 26,787 tonnes C (29,527 tons C) on 193,000 hectare (~475,000 acres) of cropland. Wheat-fallow is being grown on 89,000 hectare (~220,000 acres) of land but only 12% is utilizing moderate tillage practices. Irrigated corn is being grown on 32,000 hectare (~80,000 acres) of land with 84% utilizing moderate tillage practices. There is also 14,000 hectare (~35,000 acres) of grass planting that are sequestering 4,543 tonnes (5,000 tons) of C in 2000. This represents the diversity in the state and the varying rates of C being sequestered. Spreadsheets outlined in Appendix D provide each counties C budgets from 1990-2000 and show the differences between counties.

The effects of grazing management in each county and the associated potential C sequestered is based on an analysis of three levels of grazing intensity (light, moderate and heavy) during the growing season as described in the Phase II methods section of this report. The CSRA data provided by the local land manager's detail the percent of the rangeland in each soil map unit that were identified as being in the excellent, good, fair and poor range condition as per NRCS criteria (Figures 49-52). To estimate the potential of C sequestration on rangelands, we assumed that moving from heavy grazing events to moderate grazing events in Century would represent the change from fair and poor to a good range condition. We estimate that 5 MMTC can be sequestered over 20 years on Nebraska rangeland through the adoption of grazing management practices on areas identified as being in the fair and poor range condition. Figure 53 details the county totals across the state and details the diversity in soils, climate and history impact on the amounts of C that can be sequestered through the use of grazing management. We recognize that our analysis has not captured the intensive grazing systems.



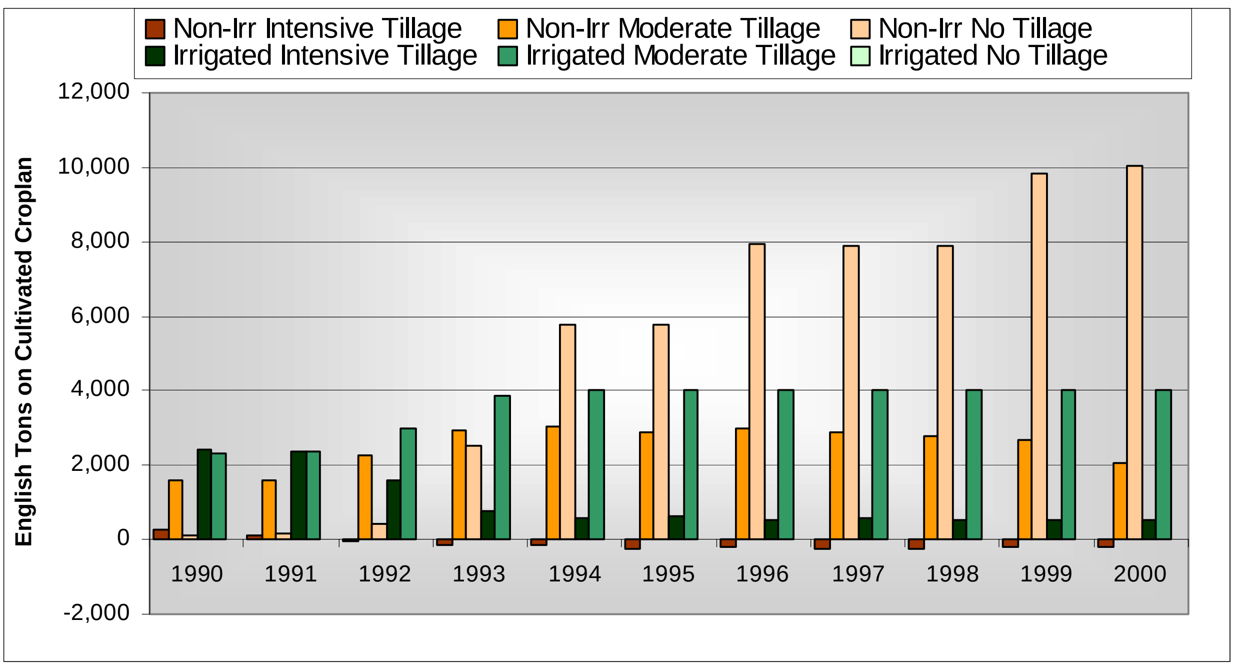
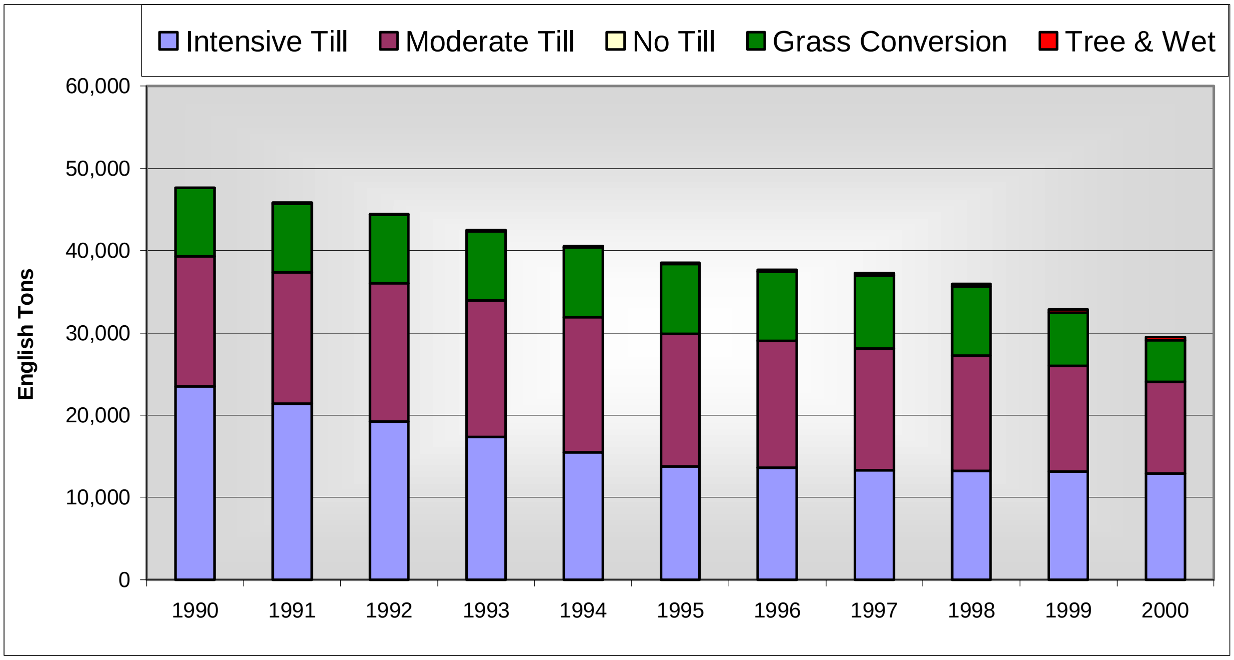


Figure 47: 1990-2000 C budgets for Dakota County Nebraska



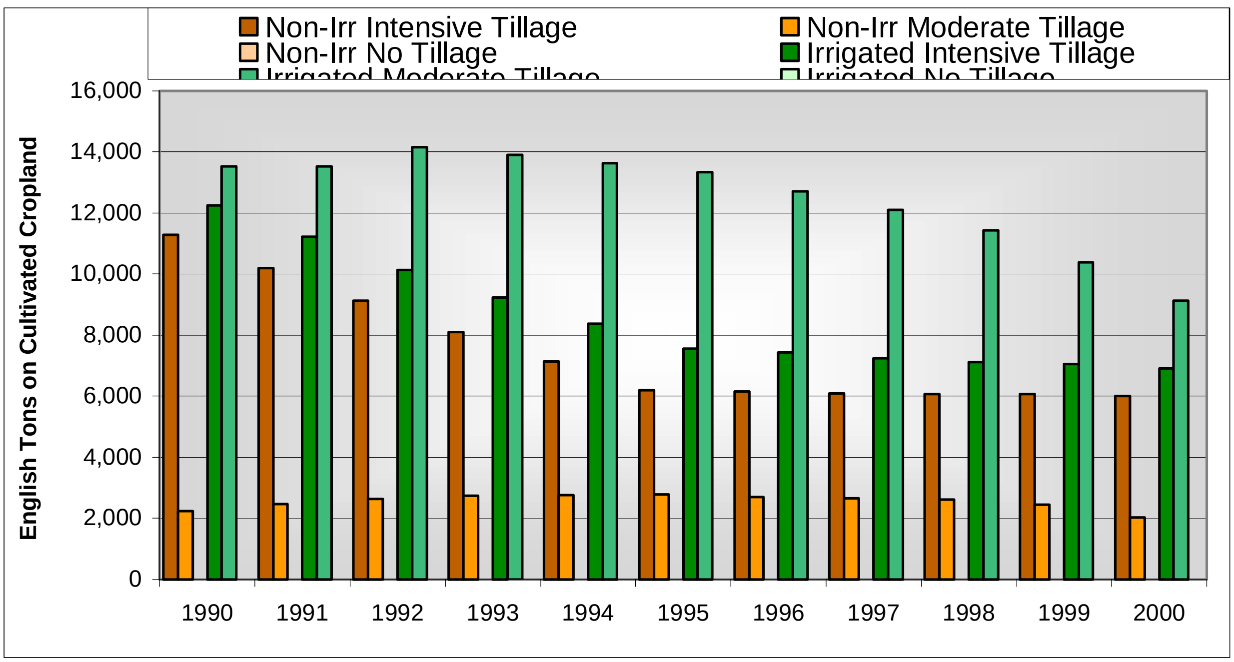


Figure 48: 1990-2000 C budgets for Perkins County Nebraska

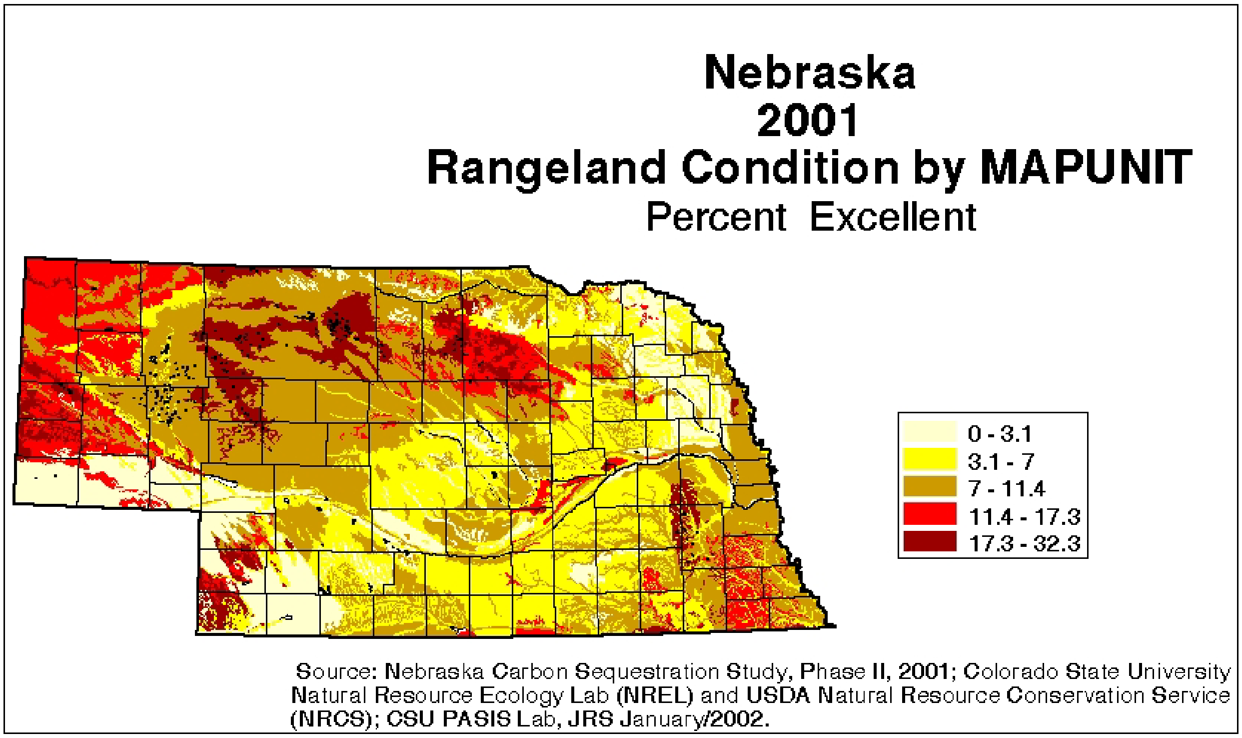


Figure 49: Nebraska rangeland identified as being in excellent condition by soil mapunit

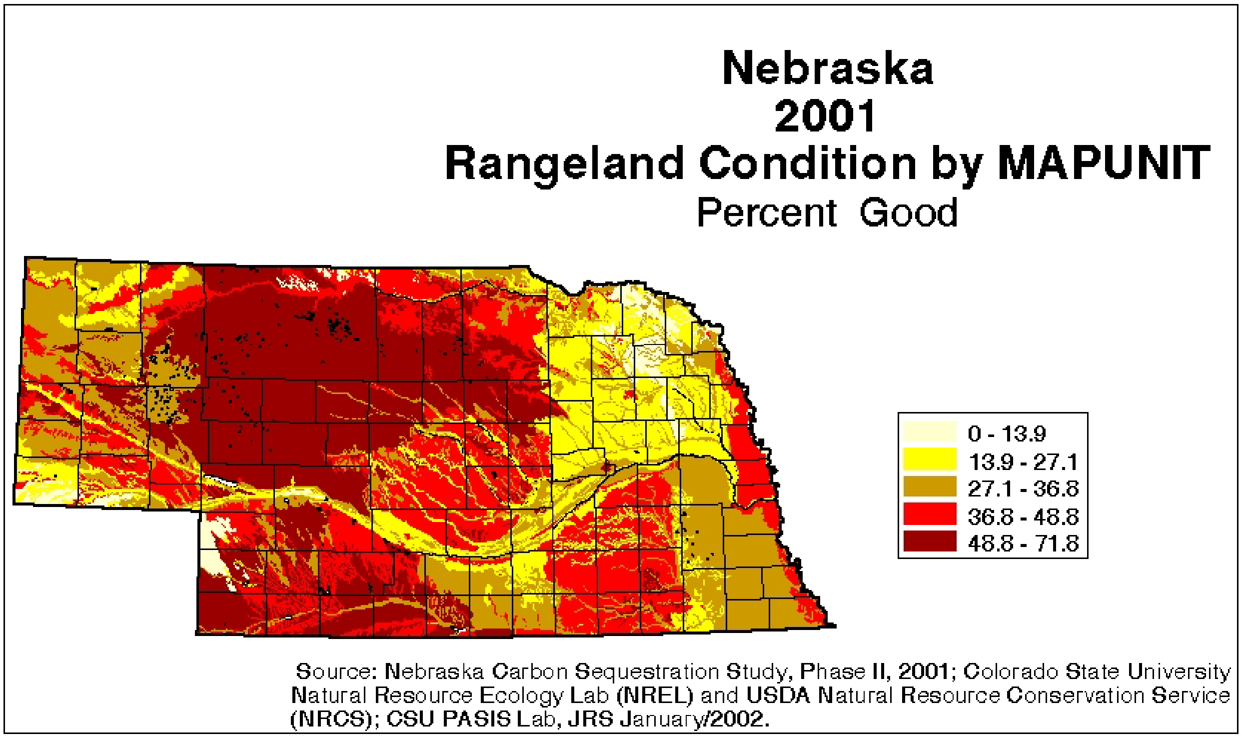


Figure 50: Nebraska rangeland identified as being in good condition by soil mapunit

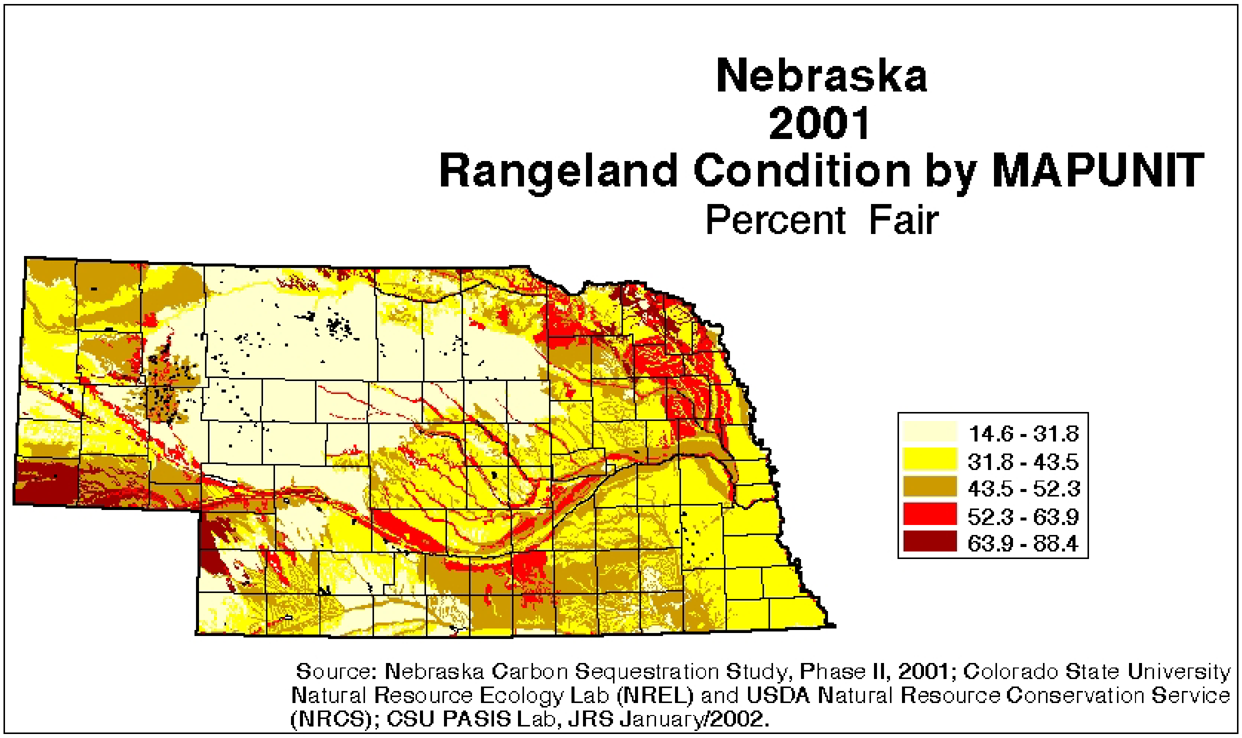


Figure 51: Nebraska rangeland identified as being in fair condition by soil mapunit

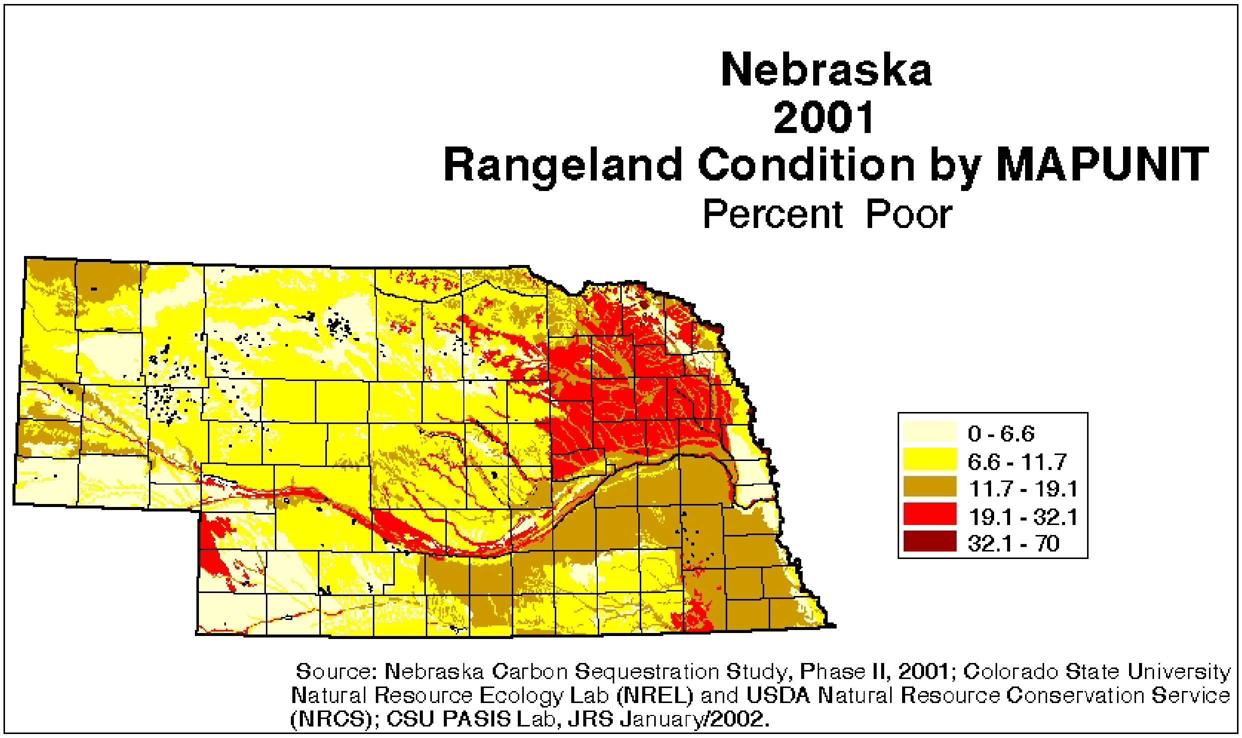


Figure 52: Nebraska rangeland identified as being in poor condition by soil mapunit

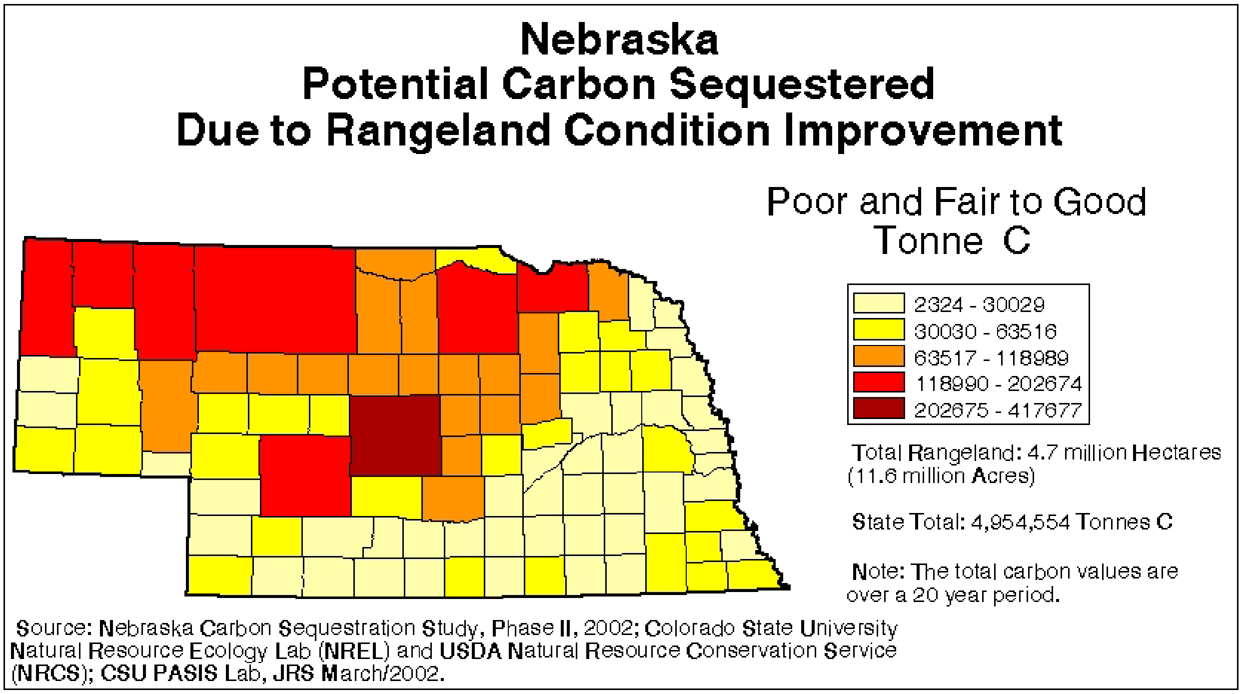


Figure 53: Nebraska potential C sequestered over 20 years due to grazing management conservation practices (currently fair and poor range conditon)

Databases

The modeled combinations of average county climates, soil types, and management sequences were simulated with approximately one million Century runs. The results were entered in a database that can be used to estimate current soil carbon changes, as well as potential C sequestration rates for the state. To provide a planning and assessment tool for land managers, model simulation results were organized into an Access (Microsoft Corp.) database with facilities to query and graph the results. The 'Nebraska CarbOn Management Evaluation Tool (COMET)' database provides this interface with supporting user manual documentation (Appendix E) and illustrative presentation (enclosed CD-ROM). The user selects the desired county, major soil types within the county, irrigated or non irrigated system and then selects from the menu crop rotations and tillage management sequences for each of two time periods (1974-1994 and 1994-2014). Two contrasting scenarios can be specified and displayed at the same time, allowing comparison of management alternatives. In addition, a table is produced showing the difference in C stock change (for both soil organic matter and crop residues) between scenarios. The data are configured to display the relative changes since the base year of 1974, but actual simulated C stocks are given in the accompanying data sheets.

Impacts

EPA estimates that Nebraska's 1999 fossil fuel combustion emissions are 11.11 MMTCE (EPA 2001). The combustion of 1.45 short tons of coal or 424 U.S. gallons of gasoline will produce 1.0 short ton of C emissions in CO_2 (EPA, 2000). Mineral soils are sequestering 1.41 million short tons of C due to the effect of conservation practices on Nebraska cropland and are removing the equivalent amount of CO_2 from the atmosphere that is produced from the combustion of 2.04 million tons, or 17,054 train cars of coal, or 0.60 billion gallons of gasoline. Decisions by land managers to use sound conservation practices on cropland are providing an offset of 12% of Nebraska's 1999 fossil fuel emissions. If C is valued at $10 per tonne, Nebraska cropland soils are providing a benefit of $12.8 million annually by current application of conservation practices by local land managers. With 43 % of Nebraska cropland using intensive tillage practices in 2000, any changes in management to move away from intensive tillage into moderate or no tillage systems will have the potential to sequester large amounts of C over time. The Nebraska COMET database provides local land managers the ability to estimate these C changes due to management changes and allows them to assess the impact of these changes.

DOE Reporting

The U.S. Department of Energy (DOE) is responsible for the development and maintenance of a GHG database (DOE, 1992). DOE provides a method for local forms of government (i.e., natural resource districts) to report sources and/or sinks of GHGs. It is recommended by the authors that these local natural resource districts acting in conjunction with the Nebraska conservation partnership report the amounts of C sequestrated by the installation of agricultural conservation practices to DOE. Voluntary reporting of GHGs using the DOE Energy Information Administration EIA, 1605(b) process allows local forms of government to report the benefits of applying conservation practices.

The calculated 2000 C sequestered, or the CO_2 being removed from the atmosphere, is shown in Table 9. These values are based on the entire analysis described, using the best available data and the local knowledge of land managers. This is the data that conservation partnership can report using 1605(b). Data for each year from 1990-2000 is available on the attached CD-ROM using spreadsheets and reflects each county value and can also be reported. Both SI and English units are shown to help convey the results to the conservation partnership in Nebraska.

Table 9: 2000 C Sequestered for each county in Nebraska

County	Metric Units			English Units		
	Hectare	Tonne C	Tonne CO_2	Acre	Ton C	Ton CO_2
Adams	122,415	34,245	125,681	302,496	37,749	138,539
Antelope	140,248	23,969	87,966	346,561	26,421	96,966
Arthur	6,335	61	225	15,655	68	248
Banner	83,736	14,254	52,313	206,918	15,713	57,665
Blaine	4,668	362	1,327	11,536	399	1,463
Boone	122,996	39,371	144,491	303,930	43,399	159,274
Box Butte	151,659	11,770	43,196	374,758	12,974	47,615
Boyd	45,473	9,920	36,408	112,368	10,935	40,133
Brown	33,697	5,200	19,084	83,267	5,732	21,036
Buffalo	142,827	28,828	105,800	352,933	31,778	116,625
Burt	115,933	19,245	70,630	286,476	21,214	77,856
Butler	126,361	20,652	75,792	312,246	22,765	83,547
Cass	116,990	6,229	22,861	289,089	6,867	25,200
Cedar	151,144	15,651	57,438	373,486	17,252	63,315
Chase	134,381	30,084	110,409	332,064	33,162	121,706
Cherry	27,083	1,209	4,437	66,923	1,333	4,891
Cheyenne	215,273	5,995	22,001	531,953	6,608	24,252
Clay	122,539	30,570	112,191	302,801	33,698	123,670
Colfax	86,782	14,901	54,686	214,444	16,425	60,281
Cuming	125,906	8,577	31,477	311,122	9,454	34,697
Custer	147,489	32,132	117,926	364,453	35,420	129,991
Dakota	55,232	18,115	66,480	136,482	19,968	73,282
Dawes	68,234	7,174	26,328	168,611	7,908	29,022
Dawson	144,755	24,370	89,439	357,697	26,864	98,589
Deuel	83,708	10,843	39,792	206,848	11,952	43,864
Dixon	113,617	34,855	127,918	280,755	38,421	141,006
Dodge	115,668	16,415	60,241	285,821	18,094	66,405
Douglas	45,232	9,576	35,144	111,772	10,556	38,740
Dundy	108,423	14,542	53,370	267,921	16,030	58,831
Fillmore	128,896	12,078	44,328	318,509	13,314	48,863
Franklin	77,366	4,763	17,480	191,176	5,250	19,269
Frontier	106,788	23,618	86,680	263,880	26,035	95,548
Furnas	116,618	13,497	49,533	288,170	14,878	54,601
Gage	162,202	9,893	36,306	400,810	10,905	40,021
Garden	68,061	5,120	18,792	168,184	5,644	20,714
Garfield	13,482	3,846	14,113	33,315	4,239	15,557
Gosper	61,747	10,364	38,037	152,581	11,425	41,929
Grant	857	462	1,697	2,117	510	1,871
Greeley	48,754	17,758	65,172	120,474	19,575	71,840
Hall	108,453	17,650	64,774	267,995	19,455	71,401
Hamilton	127,839	31,859	116,924	315,898	35,119	128,886
Harlan	85,838	17,146	62,928	212,111	18,901	69,366
Hayes	83,743	14,751	54,136	206,933	16,260	59,674
Hitchcock	100,404	11,411	41,880	248,105	12,579	46,164
Holt	135,199	-1,694	-6,216	334,084	-1,867	-6,852
Hooker	2,562	233	854	6,332	257	942
Howard	69,352	19,751	72,487	171,374	21,772	79,903
Jefferson	93,273	12,088	44,363	230,483	13,325	48,901
Johnson	64,728	8,078	29,647	159,946	8,905	32,680

County	Metric Units			English Units		
	Hectare	Tonne C	Tonne CO_2	Acre	Ton C	Ton CO_2
Kearney	116,514	22,739	83,453	287,914	25,066	91,992
Keith	101,793	4,566	16,758	251,536	5,033	18,473
Keya Paha	15,460	1,608	5,902	38,203	1,773	6,506
Kimball	167,847	26,924	98,810	414,760	29,678	108,920
Knox	127,620	19,356	71,036	315,356	21,336	78,303
Lancaster	148,240	21,727	79,740	366,310	23,950	87,898
Lincoln	172,758	15,109	55,449	426,895	16,655	61,123
Logan	17,844	-1,648	-6,048	44,094	-1,817	-6,667
Loup	7,802	1,994	7,316	19,279	2,198	8,065
Madison	117,667	12,573	46,142	290,761	13,859	50,863
McPherson	7,646	684	2,511	18,894	754	2,768
Merrick	92,174	22,381	82,139	227,768	24,671	90,543
Morrill	84,564	6,286	23,070	208,962	6,929	25,430
Nance	78,573	15,559	57,101	194,159	17,151	62,943
Nemaha	78,018	5,954	21,850	192,786	6,563	24,086
Nuckolls	99,357	22,000	80,739	245,517	24,250	88,999
Otoe	119,346	2,507	9,201	294,911	2,764	10,143
Pawnee	66,054	9,673	35,499	163,223	10,662	39,131
Perkins	193,348	26,787	98,307	477,775	29,527	108,365
Phelps	120,472	29,590	108,596	297,692	32,617	119,706
Pierce	112,461	17,980	65,988	277,898	19,820	72,739
Platte	147,530	18,302	67,167	364,556	20,174	74,039
Polk	95,514	14,068	51,628	236,022	15,507	56,910
Red Willow	110,034	12,705	46,629	271,901	14,005	51,399
Richardson	107,111	4,555	16,717	264,677	5,021	18,427
Rock	32,616	81	299	80,595	90	329
Saline	112,780	15,269	56,039	278,687	16,832	61,772
Sarpy	44,019	12,620	46,316	108,774	13,911	51,055
Saunders	166,795	19,967	73,280	412,161	22,010	80,777
ScottsBluff	110,500	6,197	22,744	273,052	6,831	25,070
Seward	114,872	29,771	109,258	283,856	32,816	120,436
Sheridan	91,167	3,154	11,575	225,279	3,477	12,759
Sherman	46,785	9,789	35,924	115,608	10,790	39,599
Sioux	31,174	1,530	5,614	77,033	1,686	6,188
Stanton	89,595	2,630	9,653	221,395	2,899	10,641
Thayer	106,090	26,911	98,764	262,155	29,664	108,869
Thomas	1,729	582	2,134	4,273	641	2,353
Thurston	84,405	23,840	87,493	208,569	26,279	96,445
Valley	53,138	21,569	79,156	131,307	23,775	87,255
Washington	82,920	3,845	14,112	204,900	4,239	15,556
Wayne	101,459	12,713	46,656	250,711	14,014	51,430
Webster	85,200	14,274	52,384	210,534	15,734	57,744
Wheeler	34,565	7,369	27,044	85,411	8,123	29,811
York	137,949	15,222	55,865	340,879	16,779	61,580

C Sequestration Rates For Conservation Practices

The Nebraska COMET database allows land managers to quantify soil C changes for present land management systems and shows what effects various conservation treatments will have on soil C changes. Table 10 provides an example of inputs needed to quantify changes in soil C due to management changes for a corn-soybean crop rotation, and also includes cropland converted to CRP. This example is for a non-hydric, loam (L) soil, non irrigated (D) in Lancaster County with a base history of corn-wheat-oat-alfalfa-milo and a recent history of corn-wheat-milo.

Table 10: Example query methods for the Nebraska COMET database

Option	Database Description	Mgmt. Sys. A	Mgmt. Sys. B
1	Crop, 75-94:	A	A
	Tillage, 75-94:	intensive tillage	intensive tillage
	Crop, 95-14:	A	A
	Tillage, 95-14:	intensive tillage	moderate tillage
2	Crop, 75-94:	A	A
	Tillage, 75-94:	intensive tillage	intensive tillage
	Crop, 95-14:	A	A
	Tillage, 95-14:	intensive tillage	no tillage
3	Crop, 75-94:	A	A
	Tillage, 75-94:	intensive tillage	intensive tillage
	Crop, 95-14:	A	B
	Tillage, 95-14:	intensive tillage	no tillage
4	Crop, 75-94:	A	A
	Tillage, 75-94:	intensive tillage	intensive tillage
	Crop, 95-14:	A	C
	Tillage, 95-14:	intensive tillage	no tillage
5	Crop, 75-94:	D	D
	Tillage, 75-94:	cur(10) no (10)	current tillage (10 yrs)-no tillage (10 yrs)
	Crop, 95-14:	B	A
	Tillage, 95-14:	no tillage	intensive tillage
6	Crop, 75-94:	D	D
	Tillage, 75-94:	cur(10) no (10)	current tillage (10 yrs)-no tillage (10 yrs)
	Crop, 95-14:	B	A
	Tillage, 95-14:	no tillage	moderate tillage

7	Crop, 75-94:	D	D
	Tillage, 75-94:	cur(10) no (10)	current tillage (10 yrs)-no tillage (10 yrs)
	Crop, 95-14:	B	A
	Tillage, 95-14:	no tillage	no tillage
8	Crop, 75-94:	E	E
	Tillage, 75-94:	cur(10) no (10)	current tillage (10 yrs)-no tillage (10 yrs)
	Crop, 95-14:	C	A
	Tillage, 95-14:	no tillage	intensive tillage
9	Crop, 75-94:	E	E
	Tillage, 75-94:	cur(10) no (10)	current tillage (10 yrs)-no tillage (10 yrs)
	Crop, 95-14:	C	A
	Tillage, 95-14:	no tillage	moderate tillage
10	Crop, 75-94:	E	E
	Tillage, 75-94:	cur(10) no (10)	current tillage (10 yrs)-no tillage (10 yrs)
	Crop, 95-14:	C	A
	Tillage, 95-14:	no tillage	no tillage

A=CORN (D)-SOYBEAN 20 yrs; B=CRP G3 1995-2014 20 yrs (100% grass); C=CRP GGCP 1995-2014 20 yrs (25% legume, 75% grass); D=CORN (D)-SOYBEAN 10 yrs - CRP 10 yrs (100% grass) 20 yrs; E=CORN (D)-SOYBEAN 10 yrs - CRP 10 yrs (25% legume, 75% grass) 20 yrs

Table 11 summarizes the soil C changes for the first 10 years due to management options as outlined in Table 10. Soil C increases as tillage disturbances decrease in options 1 and 2. Options 3 and 4 show increases in soil C when cropland is converted to permanent grass, such as buffers and grass waterways. Both grass options illustrate that by combining legumes and grasses together, the soil C increase can be increased. The CRP example also includes both grass options. If legumes were seeded when the CRP was established, then the 25% legume, 75% grass option should be used. Options 5-7 reflect what happens when CRP lands, which were planted using 100% grasses, are returned to crop production. When a crop rotation of corn-soybean using an intensive tillage system is used, soil C decreases by 0.75 tonnes ha^{-1} yr^{-1} (0.33 tons ac^{-1} yr^{-1}). A moderate tillage system also shows a decrease of 0.54 tonnes ha^{-1} yr^{-1} (0.24 tons ac^{-1} yr^{-1}), while a no tillage system is increasing soil C at a rate of 0.19 tonnes ha^{-1} yr^{-1} (0.08 tons ac^{-1} yr^{-1}). Options 8-10 reflect the result of CRP lands, planted to 25% legumes and 75% grasses, returned to crop production. When a crop rotation of corn-beans is returned, C will be loss from all tillage systems, but much reduced under no tillage. These results demonstrate how management decisions can increase or decrease soil C and how land managers can address local conditions for cropping, tillage, soils, and management systems desired by the customer.

Table 11: C sequestration rates for the first ten years after a management change

Option	Metric Units		English Units	
	Tonne C ha^{-1}	Tonne C ha^{-1} yr^{-1}	Ton C ac^{-1}	Ton C ac^{-1} yr^{-1}
1	1.7	0.17	0.8	0.08
2	6.3	0.63	2.8	0.28
3	4.9	0.49	2.2	0.22
4	9.4	0.94	4.2	0.42
5	-7.5	-0.75	-3.3	-0.33
6	-5.4	-0.54	-2.4	-0.24
7	1.9	0.19	0.8	0.08
8	-12.4	-1.24	-5.5	-0.55
9	-9.9	-0.99	-4.4	-0.44
10	-2.3	-0.23	-1.0	-0.10

Presentations, Papers And Resulting Public Awareness

Through the efforts of the researchers and conservation partners, various press articles have been published on the Nebraska C Storage Project. A compilation of these is attached in Appendix F. These articles are intended to inform the public, not only in Nebraska but throughout the U.S., of the C sequestration issue and the implications of this project. They also succeed in illustrating how local people can become a part of the debate, and how local land managers can assume a significant role in the development of science and policy.

Scientists from NREL and NRCS have made presentations in the US and internationally concerning the project and its findings and are summarized in Appendix F. These presentations were made to local land managers, state conservation partners, national policy leaders, and scientific audiences at national and international conferences. Publishing in peer reviewed scientific journals facilitates the advancement of science in C modeling and our ability to quantify rates of carbon sequestration. Several papers are currently under preparation, and will be submitted to various publishing venues. These papers describe and analyze the methods and results of the Nebraska project and comprise the basis for further research on soil C and GHGs.

Data Availability

All the data used in the analysis is archived at CSU-NREL and available by request. This includes GIS coverage's, a copy of the Century model, Century input files and CSRA relational database. The enclosed CD-ROM contains this report, the Access database 'Nebraska CarbOn Management Evaluation Tool (COMET)' database that allows the user to query the simulated results by county, soil texture/hydric characteristics, cropping systems and tillage intensity and the spreadsheet summaries detailing the total C changes attributed to conservation practices from 1990-2000.

Recommendations For Further Work

Our assessment approach was heavily model-based, utilizing a wide range of geographic databases and county-level statistics, complemented by new information on land use and management gathered using the CSRA. The existing network of long-term experiments provides a solid basis for understanding the influence of various management practices on soil carbon dynamics and are invaluable in assessing the validity of assessment models. However, the establishment of on-farm monitoring locations, where soil C changes could be directly measured over time, would enhance the present quantification approach. It would provide additional information on changes for soils and practices that are at present underrepresented in the existing field experimental network (e.g. irrigation systems, rotational grazing intensity), plus it would provide information reflecting actual on-farm conditions, rather than those of research experimental plots. The feasibility and success of such a monitoring component has been demonstrated in the Canadian Prairie Provinces project (B. McConkey, pers. comm.) and it should be possible to begin establishing such monitoring plots in conjunction with other on going activities such as soil survey. Key attributes of monitoring sites are that they be precisely georeferenced (e.g. with GPS and buried plot markers) to enable resampling at the precise location and that information on the management practices used on the site are registered. The potential exists for collaborating with farmer and natural resource districts to begin developing such a network in Nebraska. Information gathered from such a network could be used to further test and refine the model-based assessments.

The potential effects of soil erosion on CO_2 emissions and C sequestration were not included in our analysis and the influence of erosion on regional soil C balance represents an area requiring further study. Clearly, erosion can have a major effect on carbon stocks at a particular location through the transport and redistribution of soil and its associated organic matter. However the impacts will vary depending on whether the location is an erosional or depositional surface. At present, there is considerable debate as to the net effects of erosion on soil C sequestration at the landscape or regional scale. On the one hand, erosion can break up soil aggregate structures and expose protected organic matter to enhanced decomposition, which would lead to increased CO_2 emissions. On the other hand, deposition and burial of soil in lower parts of the landscape (or in lake and reservoir sediments) could result in decreased CO_2 emissions on a landscape basis. Both effects may be significant, however, there is very little information available to judge which process is dominant or whether the effects cancel out. For many of the conservation practices dealt with in our analysis (e.g. CRP, grass conversions, no-till) erosion rates are likely to be very low and thus an explicit treatment of erosion may not be critical. However, further research on carbon dynamics at the landscape scale is merited to address this issue. In any case, there is no question that the benefits of conservation practices for reducing soil erosion are extremely important, regardless of the impacts of erosion on soil C sequestration.

The focus of the assessment has been on strategies to mitigate CO_2 increase, through carbon sequestration. However, the resource and land use/land management data compiled in this study form a solid basis for more comprehensive estimates of greenhouse gas emissions and mitigation potential, including estimating fluxes of N_2O and CH_4 fluxes associated with cropping practices and CO_2 emissions associated with agricultural inputs, such as fuel use, fertilizer manufacture and energy required for irrigation. Both standard accounting approaches such as the IPCC inventory methodology and dynamic models of N_2O and CH_4 emissions can be applied using the resource data and other information collected in the CSRA. Significant options exist for agricultural mitigation of non-CO_2 greenhouse gases and assessment of these potentials would be greatly facilitated by the data and information that have been compiled in the present project.

The use of agriculture products and residues as a source of renewable fuels is attracting interest from public and private entities. This analysis along with the supporting databases can provide useful information and a solid basis for more comprehensive estimates of biomass availability while address other environmental issues such as erosion control and soil C.

Conclusions

The data provided by the Natural Resource Districts in Nebraska, the Century simulations, and the resulting public outreach support the following seven conclusions:

1. Nebraska cropland soils are shown as a C sink prior to 1990 and continuing to sequester C over time. These soils in 2000 are removing 1.28 MMTC (~4.7 MMT of CO_2) from the atmosphere mainly through the adoption of conservation practices.
2. Nebraska rangeland has the potential to sequester 5 MMTC (18.4 MMT of CO_2) from the atmosphere over a 20 year period through the adoption of grazing management practices on areas identified as being in poor or fair condition.
3. Using results from this study, local land managers, working with local conservation planners have the ability to estimate rates of soil C change (C sequestration) depending on the types of management decisions that are implemented.
4. The CSRA provides a tool to help gather local land use data.
5. Nebraska NRD’s have the necessary data to report to the U.S. DOE, through the use of the EIA-1605 (b) reporting procedures, the C sequestered by the implementation of conservation practices.
6. The Nebraska Conservation Partnership, including NRD’s, state agencies, and NRCS, were willing to take a leadership role aimed at increasing awareness of the C sequestration issue and the role of agriculture.
7. 100% of the Nebraska NRD’s were willing to participate in research dealing with C sequestration and to provide the valuable local information that is necessary to enhance C simulation computer modeling.

References

Alexander, R.B. and R.A. Smith. 1990. County-level estimates of nitrogen and phosphorous fertilizer use in the United States, 1945-1985. U.S. Geological Survey Open-File Report 90-130. http://water.usgs.gov/pubs/ofr/ofr90130/data.html.

Allmaras, R.R., H.H. Schomberg, C.L. Douglas Jr. and T.H. Dao. 2000. Soil organic carbon sequestration potential of adopting conservation tillage in U.S. croplands. J. Soil Water Conserv. 55:365-373.

Anonymous, 1924. Fertilizer used on cotton, 1923-1924. Table 753 from: Miscellaneous Agricultural Statistics. 1924 Yearbook of the Department of Agriculture. Page 1171.

Armentano, T.V. and J.T.A. Verhoeven. 1990. Biogeochemical Cycles: Global. In: B.C. Patten . (eds). Wetlands and Shallow Continental Water Bodies. Vol 1. SPB Academic Publishing, The Hague, The Netherlands. pp. 281-311.

Bogue, A.G. 1963. From Prairie to Corn Belt: Farming on the Illinois and Iowa prairies in the Nineteenth Century. University of Chicago Press, Chicago, IL.

Bonnen, C.A., and F.F. Elliot. 1931. Type of farming areas in Texas. Bull. No. 427. Texas Agricultural Experiment Station. Agricultural and Mechanical College of Texas.

Brenner, J., K. Paustian, G. Bluhm, J. Cipra, M. Easter, E.T. Elliott, T. Kautza, K. Killian, J. Schuler and S. Williams. 2001. Quantifying the change in greenhouse gas emissions due to natural resource conservation practice application in Iowa. Final report to the Iowa Conservation Partnership. Colorado State University Natural Resource Ecology Laboratory and USDA Natural Resources Conservation Service, Fort Collins, CO, USA.

Brenner, J., K. Paustian, G. Bluhm, K. Killian, J. Cipra, B. Dudek, S. Williams and T. Kautza. 2002. Analysis and Reporting of Carbon Sequestration and Greenhouse Gases for Conservation Districts in Iowa. In: J.M. Kimble, R. Lal, R.F. Follett, and B.A. Stewart (eds). Agriculture Practices and Policies for Carbon Sequestration in Soil. CRC Press, Baca Raton, FL., USA.

Brooks, W.P. 1901. Agriculture Vol. II: Manures, fertilizers and farm crops, including green manuring and crop rotation. The Home Correspondence School. King-Richardson Co., Publishers. Springfield, MA.

Carter, M. R., W. J. Parton, I.C. Rowland, J. E. Schultz and G. R. Steed. 1993. Simulation of soil organic carbon and nitrogen changes in cereal and pasture systems of Southern Australia. Australian Journal of Soil Research, 31:481-491.

Chilcott, E.C. 1910. A study of cultivation methods and crop rotations for the Great Plains area. USDA Bureau of Plant Industry. Bull. No. 187.

Cochrane, W.W. 1993. The Development of American Agriculture: A Historical Analysis. Second Edition. University of Minnesota Press, Minneapolis, MN.

Cole, C.V., K. Flach, J. Lee, D. Sauerbeck and B. Stewart. 1993. Agricultural sources and sinks of carbon. Water, Air, and Soil Pollution, 70:111-122.

CTIC. 1998. 1998 Crop residue management executive summary. Conservation Technology Information Center. Online data at http://www.ctic.purdue.edu/Core4/CT/CT.html.

Daly, C., R. P. Neilson, and D. L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology 33: 140-158.

DOE. 1992. Title XVI of the Energy Policy Act of 1992, Section 1605(b). United States Depart of Energy.

Elliot, F.F., J.W. Tapp, and R.E. Willard. 1928. Types of farming in North Dakota. USDA Technical Bull. No. 102.

Elliot, F.F. 1933. Types of Farming in the United States. Census of Agriculture. Fifteenth Census of the United States.

Elliott, E. T. and C.V. Cole. 1989. A perspective on agroecosystem science. Ecology 70:1597-1602.

Ellsworth, J.O. 1929. Types of farming in Oklahoma. Bull. No. 181. Agricultural Experiment Station. Oklahoma Agricultural and Mechanical College.

EPA. 2000. Inventory of US Greenhouse Gas Emissions and Sinks: 1990-1998. Office of Policy, Washington, D.C.

EPA. 2001. State Energy CO_2 Inventories. Data available online at http://yosemite.epa.gov/globalwarming/ghg.nsf/emissions/CO2EmissionsBasedOnStateEnergyData.

ESRI. 2001. Environmental Systems Research Institute, Inc. Redlands, CA. USA.

R.F. Follett. 2001. Organic Carbon Pools in Grazing Land Soils. In: R.F. Follett, J.M. Kimble and R. Lal (eds). The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect. pp. 65-86. CRC Press, Boca Raton, FL, USA.

Fraps, G.S., and S.E. Asbury. 1931. Commercial fertilizers in 1930-31 and their uses. Texas Agricultural Experiment Station. Bull. No. 434. Agricultural and Mechanical College of Texas.

GAP. 1993. Nebraska Gap Analysis Program. Draft land cover data. University of Nebraska, Lincoln, Center for Advanced Land Management Information Technologies (CALMIT). Lincoln, Nebraska.

Garey, L. F. 1929. Types of farming in Minnesota. Bull. No. 257. Agricultural Experiment Station. University of Minnesota.

Hanna, M. and L. Van Fossen. 1990. Profitable corn harvesting. Iowa State University Extension Service, Publication # Pm-574. Available online at http://www.ae.iastate.edu/mp574.htm.

Hardies, E.W., and A.N. Hume. 1927. Wheat in South Dakota. Bull. No. 222. Agricultural Experiment Station of the South Dakota State College.

Hargreaves, M.W.M. 1993. Dry Farming in the Northern Great Plains: Years of readjustment 1920-1990. University Press of Kansas, Lawrence, KS.

Hodges, J.A., F.F. Elliot, and W.E. Grimes. 1930. Types of farming in Kansas. Bull. No. 251. Agricultural Experiment Station, Kansas State Agricultural College.

Holmes, G.K. 1903. Practices in crop rotation. 1902 Yearbook of the Department of Agriculture. Pages 519-532.

Holmes, C.L. 1929. Types of farming in Iowa. Bull. No. 256. Agricultural Experiment Station. Iowa State College of Agricultural and Mechanic Arts.

Hurd, E.B. 1929. The corn enterprise in Iowa. Bull. No. 259. Agricultural Experiment Station. Iowa State College of Agriculture and Mechanic Arts.

Hurd, E.B. 1930. Cropping Systems in Iowa - Past and Present. Bull. No. 268. Agricultural Experiment Station. Iowa State College of Agriculture and Mechanic Arts.

Hurt, R.D. 1994. American Agriculture: A brief history. Iowa State University Press, Ames, IA.

Ibach, D.B., and J.N. Mahan. 1968. Fertilizer use patterns and potentials. Chapter I in: Changing Patterns in Fertilizer Use. R.C. Dinauer (ed.). Soil Science Society of America, Inc. Pp. 1-31.

Iowa State College Staff Members. 1946. A Century of Farming in Iowa: 1846-1946. Iowa State College Press. Ames, Iowa.

IPCC. 1996. Climate Change 1995: The IPCC Second Assessment Report, Volume 2: Scientific-Technical Analyses of Impacts, Adaptations, and Mitigation of Climate Change, Watson, R.T., M.C. Zinyowera, and R.H. Moss (eds.). Cambridge University Press: Cambridge and New York.

Keeling, C.D. and T.P. Whorf. 2000. Atmospheric CO2 records from sites in the SIO air sampling network. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. Data available online at http://cdiac.esd.ornl.gov/ftp/maunaloa-co2/maunaloa.co2.

Kezer, A. ca. 1920. Dry Farming in Colorado: Pertinent facts about conditions to be found and methods to be used which should be known by every person who contemplates locating on dry land in Colorado. Colorado State Board of Immigration, Denver, CO.

Lal R., R.F. Follett, J.M. Kimble and C.V. Cole. 1998. The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect. Ann Arbor Press, Chelsea, MI. 128 p.

Larson, C.W., L.M. Davis, C.A. Juve, O.C. Stine, A.E. Wright, A.J. Pistor, and C.F. Langworthy. 1922. The dairy industry. Yearbook of the Department of Agriculture, 1922. Pages 281-394.

Latta, W.C. 1938. Outline History of Indiana Agriculture. Alpha Lambda Chapter of Epsilon Sigma Phi, Publishers.

Leighty, C.E. 1938. Crop rotation. In: Soils and Men. 1938 Yearbook of Agriculture, USDA. Pages 406-430.

Metherall, A.K., L.A. Harding, C.V. Cole, and W.J. Parton. 1993. CENTURY SOM Model Environment, Technical Documentation, Agroecosystem Version 4.0. GPSR Unit, Technical Report No. 4. USDA-ARS. Fort Collins, CO

Miner, C. 1998. Harvesting the High Plains: John Kriss and the business of wheat farming, 1920-1950. University Press of Kansas, Lawrence, KS.

NASS. 1995-1999. Published Estimates Database. USDA-National Agricultural Statistics Service. Data available online at <http://www.nass.usda.gov:81/ipedb/>

NASS. 2000. Published Estimates Database. USDA-National Agricultural Statistics Service. Data available online at <http://www.nass.usda.gov:81/ipedb/>

NRI 1997. Natural Resources Inventory Division. Natural Resources Conservation Service. U.S. Department of Agriculture. http://www.nhq.nrcs.usda.gov/MLH/nritest/nri_data.html.

NDSU. 1997. Corn production guide – corn harvesting. North Dakota State University Extension Service, Publication #A-1130. Available online at http://www.ext.nodak.edu/extpubs/plantsci/rowcrops/a1130-10.htm.

Neftel, A., H. Friedli, E. Moor, H. Lötscher, H. Oeschger, U. Siegenthaler, and B. Stauffer. 1994. Historical CO_2 record from the Siple Station ice core. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Data available online at http://cdiac.esd.ornl.gov/ftp/trends/co2/siple2.013.

Parton, W.J., D.S. Schimel, C.V. Cole, and D.S. Ojima. 1987. Analysis of factors controlling soil organic matter levels in Great Plains grasslands. Soil Sci. Soc. Am. J. 51:1173-1179.

Parton, W.J., J.W.B. Stewart, and C.V. Cole. 1988. Dynamics of C, N, P and S in grassland soils: A model. Biogeochemistry 5:109-131.

Parton, W. J., and P. E. Rasmussen. 1994. Long-term effects of crop management in wheat/fallow: II. CENTURY model simulations. Soil Sci. Soc. Am. J., 58:530-536.

Paul, E.A., K. Paustian, E.T. Elliott and C.V. Cole (eds). 1997. Soil organic matter in temperate agroecosystems: Long-term Experiments in North America. CRC Press, Boca Raton, FL, USA. 414 p.

Paustian, K., W. J. Parton, and J. Persson. 1992. Modeling soil organic matter in organic-amended and nitrogen-fertilized long-term plots. Soil Sci. Soc. Am. J., 56:476-488.

Paustian, K., E.T. Elliott, H.P. Collins, C.V. Cole and E.A. Paul. 1995. Use of a network of long-term experiments for analysis of soil carbon dynamics and global change: The North America model. Aust. J. Exper. Agr. 35: 929-939.

Paustian, K., E. T. Elliott, G. A. Peterson and K. Killian. 1996. Modelling climate CO_2 and management impacts on soil carbon in semi-arid agroecosystems. Plant and Soil, 187:351-365.

Paustian, K., E. T. Elliott and K Killian. 1997a. Modeling soil carbon in relation to management and climate change in some agroecosystems in central North America. In: R. Lal, J. M. Kimble, R. F. Follett and B. A. Stewart (eds). Soil Processes and the Carbon Cycle. pp. 459-471. CRC Press, Boca Raton, FL, USA.

Paustian, K., O. Andren, H. Janzen, R. Lal, P. Smith, G. Tian, H. Tiessen, M. van Noordwijk and P. Woomer. 1997b. Agricultural soil as a C sink to offset CO_2 emissions. Soil Use and Management 13:230-244.

Paustian, K., C.V. Cole, D. Sauerbeck and N. Sampson. 1998. CO_2 mitigation by agriculture: An overview. Climatic Change 40:135-162.

Paustian, K., E.T. Elliott, J. Six and H.W. Hunt. 2000. Management options for reducing CO_2 emissions from agricultural soils. Biogeochemistry 48:147-163.

Paustian, K., K. Killian, J. Cipra, G. Bluhm, J.L. Smith and E.T. Elliott. 2001. Modeling and regional assessment of soil carbon: A case study of the Conservation Reserve Program. In: R. Lal and K. McSweeney (eds) Soil Carbon Sequestration and the Greenhouse Effect. SSSA Special Publ. 57. SSSA Madison, WI.

Paustian, K, J. Brenner, K. Killian, J. Cipra, S. Williams, T. Kautza and G. Bluhm. 2002. State-level analyses of C sequestration in agricultural soils. In: J.M. Kimble, R. Lal, R.F. Follett, and B.A. Stewart (eds). Agriculture Practices and Policies for Carbon Sequestration in Soil. CRC Press, Boca Raton, FL., USA.

Piper, C.V., R.A. Oakley, H.N. Vinall, A.J. Pieters, W.J. Morse, W.J. Spillman, O.C. Stine, J.S. Cotton, G.A. Collier, M.R. Cooper, E.C. Parker, E.W. Sheets, and A.T. Semple. 1924. Hay. Yearbook of Agriculture, 1924. Pages 285-376.

Reilly, J.M. and K.O. Fuglie, 1998. Future yield growth in field crops: what evidence exists? Soil & Tillage Research 47:275-290.

Ross, W.H., and A.L. Mehring. 1938. Mixed Fertilizers. In: Soils and Men. 1938 Yearbook of Agriculture, USDA. Pages 522-545.

Russell, E.Z., S.S. Buckley, O.E. Baker, C.E. Gibbons, R.H. Wilcox, H.W. Hawthorne, S.W. Mendum, O.C. Stine, G.K. Holmes, A.V. Swarthout, W.B. Bell, G.S. Jamieson, C.W. Warburton, and C.F. Langworthy. 1922. Hog Production and Marketing. Yearbook of the Department of Agriculture, 1922. Pages 181-280

Saltzer, R.M. and C.J. Schollenberger. 1938. Farm Manure. In: Soils and Men. 1938 Yearbook of Agriculture, USDA. Pages 445-461.

Schimel, D. 1995. Terrestrial ecosystems and the carbon cycle. Global Change Biology 1:77-91.

Schlesinger, W.H. 1991. Biogeochemistry: an analysis of global change. Academic Press, San Diego, California.

Sisk, T.D., editor. 1998. Perspectives on the land-use history of North America: a context for understanding our changing environment. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR 1998-0003 (Revised September 1999). 104 pp.

Smith, C.B. 1912. Rotations in the Corn Belt. 1911 Yearbook of the Department of Agriculture. Pages 325-336.

Smith, P., J.U. Smith, D.S. Powlson, W.B. McGill, J.R.M. Arah, O.G. Chertov, K. Coleman, U. Franko, S. Frolking, D.S. Jenkinson, L.S. Jensen, R.H. Kelly, H. Klein-Gunnewiek, A.S. Komarov, C. Li, J.A.E. Molina, T. Mueller, W.J. Parton, J.H.M. Thornley and A.P. Whitmore. 1997. A comparison of the performance of nine soil organic matter models using datasets from seven long-term experiments. Geoderma. 81:153-225.

Spillman, W.J. 1903. Systems of farm management in the United States. 1902 Yearbook of the Department of Agriculture. Pages 343-364.

Spillman, W.J. 1906. Diversified farming in the cotton belt. 1905 Yearbook of the Department of Agriculture. Pages 193-218.

Spillman, W.J. 1908. Cropping systems for stock farms. 1907 Yearbook of the Department of Agriculture. Pages 385-398.

Spillman, W.J. 1909. Types of farming in the United States. 1908 Yearbook of the Department of Agriculture. Pages 351-366.

USDA-FSA. 2000. Conservation Reserve Program data set. Kansas City, Missouri

USDA-SCS. 1994. State Soil Geographic Data Base (STATSGO) Data User Guide. United States Department of Agriculture Soil Conservation Service, National Soil Survey Center, Lincoln, Nebraska.

U.S. Global Change Research Program. 2000. Climate Change, State of Knowledge. Available online at http://www.nacc.usgcrp.gov.

Wander et al., 1998. Tillage impacts on depth distribution of total and particulate organic matter in three Illinois soils. Soil Sci. Soc. Am. J. 62:1704-1711.

Warren, J.A. 1911. Agriculture in the central part of the semiarid portion of the Great Plains. USDA Bureau of Plant Industry. Bull. No. 215.

West, T.O. and G. Marland. 2001. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: comparing tillage practices in the United States. Agric. Ecosys. Environ. (in press).

Wilhelmi. 1999. Methodology for assessing vulnerability to agricultural drought: A Nebraska Case Study. PhD dissertation. University of Nebraska. Lincoln, Nebraska.

Acknowledgments

Funding for the Phase I activities were made available by grants from the Nebraska Public Power District, Corn Board, Farm Policy Task Force and the Department of Energy. Funding for the Phase II activities were made available by grants from the Nebraska Environmental Trust. The project also recognizes the following groups who played an important role:

- Nebraska NRCS for providing information to the assessment team, guidance and support to local NRD's,
- Nebraska Department of Natural Resources and University of Nebraska for overall project support and providing resource data,
- Nebraska NRD's for providing local data knowledge.

Appendix A: Irrigated Land Geospatial Database

The Nebraska Statewide Pivot and Surface Irrigation geospatial database - (N)ebraska (I)rrigation from (M)ultiple (D)ata (S)ources (NIMDS) - is a combination of two existing Arc/Info (ESRI, 2001) datasets: The (CO)operative (HY)drology (ST)udy in the Central Plattte River Basin (COHYST) and the drought mitigation dataset (WILHELMI) developed by Wilhelmi, 1999. These data were provided by the University of Nebraska, Lincoln, Center for Advanced Land Management Information Technologies (CALMIT). The NIMDS irrigated acreage for the state is calculated at 7,859,000. Comparison of NIMDS irrigated areas by county to the 1997 National Resource Inventory (NRI) data and the 1995-1999 National Agriculture Statistics Service (NASS) data show a high correlation between the different data sources (NRI, 1997; NASS, 1995-1999).

The COHYST geospatial database is a pivot and surface irrigation inventory that covers 43 of the 93 Nebraska counties (4,136,472 acres). The data were developed from 1997 LandSat Thematic Mapper (TM) Imagery. Twenty-three of the forty-three counties were field checked for accuracy by local Nebraska Resource Districts (NRD's). However, only 20 counties have complete coverage's. COHYST consists of two separate coverage's - pivot features and surface irrigation features. These were processed into a single theme using the Arc/Info UNION command. A common attribute, "irrigation type", was added prior to merging to denote the original themes irrigation method - pivot or surface. This merged COHYST data was used as a starting point for the final statewide irrigation coverage NIMDS.

WILHELMI data was used to supplement irrigation information for those areas missing from the COHYST coverage. The WILHELMI irrigated layer was developed using 1991 through 1993 growing season LandSat Thematic Mapper (TM) Imagery at a 40 meter resolution. Irrigated areas were compiled using ArcView heads-up digitizing in the Albers Conic Equal Area Projection, NAD 27. The projection parameters are not documented, however, it is thought that the Central Meridian and Standard Parallels are referenced to the coterminous United States. Data error was calculated by comparing the digitized areas by county to state statistics. Overall, the difference between WILHELMI and state statistics was within 0 to 8 percent. The final shape file was then converted to an Arc/Info coverage.

According to the state experts, the WILHELMI data is believed to over-estimate irrigation for Nebraska (G. Henebry, personal comm). This data error may be due to digitizing methods or imagery misclassification due to differences in time of the Landsat data. Visual inspection of the WILHELMI data show that many of the irrigation polygons are distorted - pivots that should be circular are represented with odd shapes and angles. This error is likely from the conversion of the original shape file to a vector coverage. The tolerances that default to the bounding area of the shape file were set too large resulting in data generalization during the conversion. Additionally, some pivot and surface irrigated areas were digitized as large irregular shapes instead of detailed individual polygons as compared to the same areas in the COHYST layer. Attribute values that determine irrigated and non-irrigated polygons are missing in the WILHELMI dataset resulting in no distinction between surface, pivot, and no data areas in the coverage. For our use, a major problem with the WILHELMI data was the geographic feature positioning mis-alignment as compared with other data sources. Irrigation polygons are incorrectly positioned in relation to cropland areas from the GAP land cover dataset (GAP, 1993) and the same irrigated areas from the COHYST theme. This error is more apparent in the western half of the state where polygons are shifted to the southwest. The positioning mis-alignment was likely caused because the selected projection is problematic for states like Nebraska that lie in an east/west plane and the projection parameters were defined incorrectly compounding the data error as the features move out from the Central Meridian defined at 96 degrees.

Before the WILHELMI data was used, the data problems needed correction. Using the Arc/Info ARC EDIT module, a new attribute, "irr-code", was added to the coverage. The WILHELMI dataset pivot and surface polygons were assigned a single irrigation attribute by selecting all polygons smaller than the largest background polygon in the coverage. This procedure identified the majority of the irrigated polygons. However, small island polygons representing spaces between irrigated areas are still erroneously labeled as "irrigated" (Figure A1). These attribute errors were determined to be acceptable due to manpower limitations. After the WILHELMI data were attributed, polygon information inside the COHYST boundary were deleted using the Arc/Info ERASE command. This step removed 7,088,000 hectares (17,508,000 acres) in the WILHELMI coverage. Upon visual inspection of the remaining polygons outside of the COHYST boundary, it was determined that only the southwest corner of the WILHELMI dataset was significantly mis-aligned in relation to the GAP cropland data.

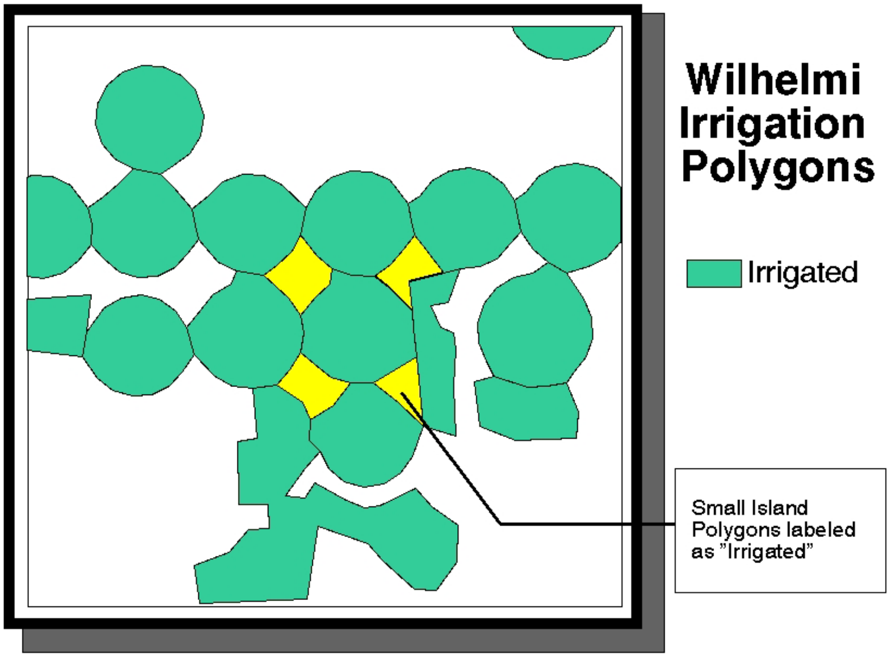


Figure A1: WILHELMI Irrigation Polygons

A boundary layer of this southwest region was generated and used as the clipping and erase area with the Arc/Info CLIP and ERASE commands. A total of 855,000 hectares (2,113,000 acres) were removed from the southwest region of the altered WILHELMI theme and saved to a new coverage (Figure A2). The remaining 12,089,000 hectares (29,861,000 acres) in the northern and eastern areas outside the COHYST boundary in the altered WILHELMI layer received no further adjustment. Extracting cropland areas from the GAP land cover grid using the Arc/Info SELECT command developed a statewide irrigation control data layer. Visual analysis of the GAP cropland areas showed circular polygon features that could be easily identified as irrigation pivots. Additionally, these pivot features visually coincided with the COHYST pivot features. The resulting cropland grid data were filtered to remove data noise and then converted into an Arc/Info vector coverage. The southwest WILHELMI coverage was georeferenced using the GAP cropland coverage as the ground control. Tics were visually identified and digitized as TO and FROM positions for the Arc/Info ADJUST command. These tics were used to shift groups of polygon features in the southwest WILHELMI data subset to their correct geographic position (Figure A3). A total of 785 TO and FROM tics were manually generated to correct the positional errors found within the southwestern half of the WILHELMI theme.

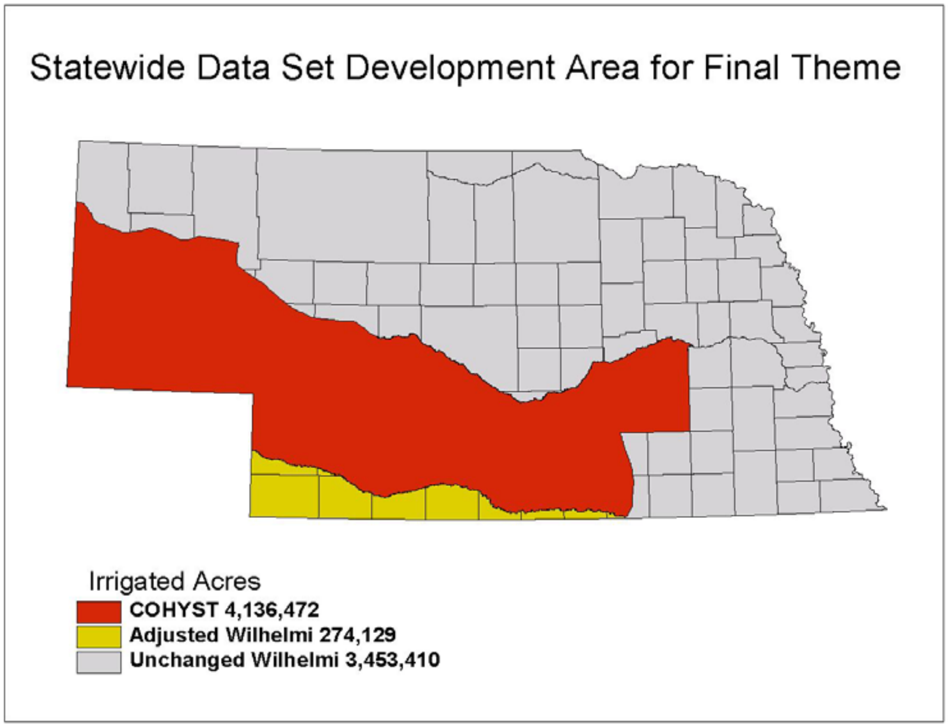


Figure A2: Statewide Dataset Development Areas

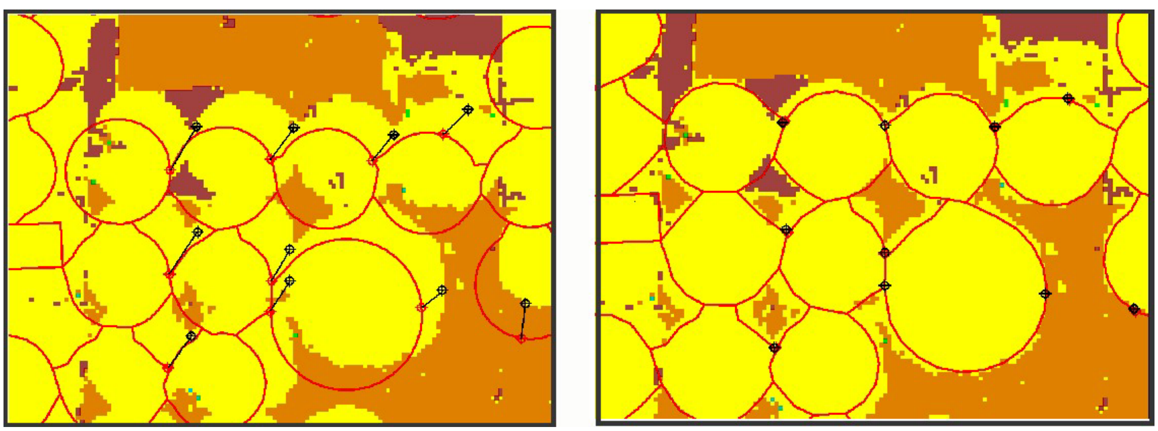


Figure A3: Southwest WILHELMI Irrigaton Adjustment

The final statewide NIMDS irrigation layer was assembled using the Arc/Info MAPJOIN command. The merged COHYST pivot and surface features, the corrected WILHELMI features, and the remaining WILHELMI features were assembled to create the statewide irrigation coverage. Some manual attribute adjustment was needed along the boundary of the joined areas. The final Arc/Info vector coverage was converted to an irrigation grid at 30-meter resolution for further analysis with the GAP land cover data.

Land Use/Land Cover Geospatial Database

The Nebraska Land Use/Land Cover raster dataset is a digital product based on the draft statewide Land Cover Map of Nebraska (GAP, 1993) and the Nebraska Pivot and Surface Irrigation (NIMDS) coverage. The original 20 class GAP raster dataset was generalized using the Arc/Info RECLASS command resulting in the following classifications: Cropland, Range, Fallow, Forest, Urban, Bottom Land, and Water (Table A1).

Table A1: Reclassification of GAP Land Cover Data.

Original Classification	New Classification
Agricultural Fields	Cropland
Fallow Ag Fields	Fallow Cropland
Sandsage Shrubland, Sandhills Upland Prairie, Lowland Tallgrass Prairie, Upland Tallgrass Prairie, Little Bluestem - Grama Mixedgrass Prairie, Western Wheatgrass Mixedgrass Prairie, Western Mixedgrass Prairie, Barren/Sand/Outcrop	Range
Ponderosa Pine, Deciduous Forest/Woodland, Evergreen Forest/Woodland	Forest
Aquatic Bed Wetland, Emergent Wetland Bottom Land, Riparian Shrubland, Riparian Woodland	Bottom Land
Open Water	Water
Low Intensity Residential, Commercial/Industrial/Transportation	Urban

Irrigated land cover classes were identified by masking the reclassified raster using the irrigation grid at 30 meters resolution developed from the Nebraska Pivot and Surface Irrigation (NIMDS) coverage. The agricultural land use classifications inside the irrigated areas were assigned to: Irrigated Cropland, Irrigated Hayland, and Irrigated Fallow. Any irrigated areas classified as Forest, Bottom Land, Urban, or Water was dropped out of the irrigation area. This adjustment resulted in 182,000 acres being removed from the irrigation area. The difference in acreage between the NIMDS irrigation raster (7,858,757) and the final product's irrigated land acreage (7,676,000) can be attributed to an overestimate of Nebraska's irrigated lands in the source coverage.

Merging the irrigation land cover raster with the reclassed GAP land cover raster, produced the final product (Figure 4A). Nebraska land use/land cover classification statistics are documented in Table A2.

Table A2: Land use/Land Cover Areas.

Classification	Area (Hectare)	Area (Acre)	Percentage of State Land Area
Non-irrigated Cropland	4,579,911	11,312,380	22.9
Irrigated Cropland	2,824,404	6,976,277	14.1
Fallow	499,279	1,233,220	2.5
Irrigated Fallow	21,000	51,871	0.1
Range	10,783,259	26,634,649	53.8
Irrigated Hayland	262,394	648,113	1.3
Forest	472,074	1,166,024	2.4
Water	145,519	359,433	0.7
Bottom Land	278,921	688,936	1.4
Urban	169,270	418,097	0.8

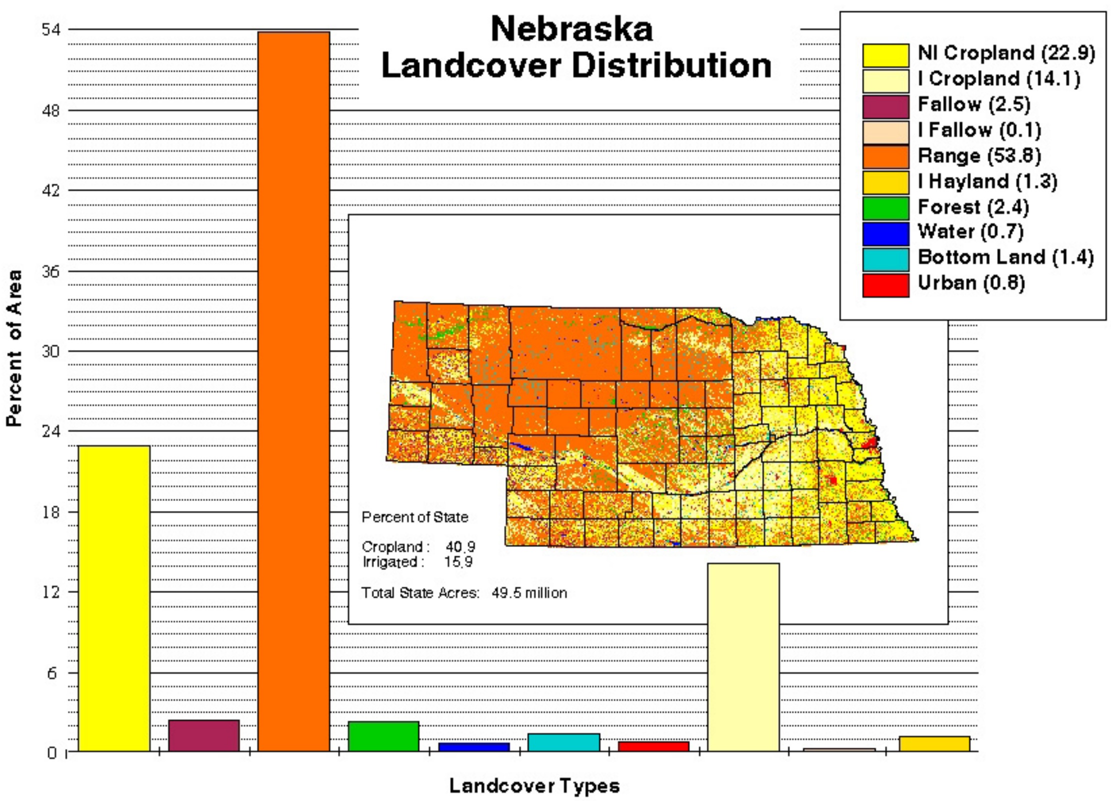


Figure A4: Nebraska Land Cover Distribution

Appendix B: CSRA Example Data Sheets

Current Land Use Information

CARBON SEQUESTRATION RURAL APPRAISAL

CURRENT LAND USE INFORMATION FROM LOCAL KNOWLEDGE (Land Use)

STATE NEBRASKA **COUNTY** CHASE

FOR INDICATED SOILS ON MAP DETERMINE: MUID (STATSGO ASSOCIATION)	NE008	NE020	NE021	NE033	NE039	NE066	NE067	NE068	NE074	NE110
TOTAL ACRES IN MUID	5,456	21,672	49,578	1,339	27,176	98,920	5	6,314	39,886	132,795
LAND USE INFORMATION										
TOTAL DRYLAND CROPLAND	12.3%	12.0%	10.2%	9.8%	16.6%	20.4%	20.0%	22.8%	38.3%	26.3%
CLASS I & II	49%	39%	53%	0%	46%	42%	55%	30%	92%	69%
CLASS III & IV	18%	32%	26%	27%	17%	38%	0%	67%	4%	29%
CLASS V & VI	33%	29%	21%	73%	37%	20%	45%	3%	4%	2%
Dryland Cropland SubTotal	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
TOTAL IRRIGATED CROPLAND	13.6%	16.2%	4.1%	20.4%	19.5%	49.8%	80.0%	53.1%	13.9%	53.4%
CLASS I & II	79%	40%	72%	0%	56%	40%	95%	43%	97%	60%
CLASS III & IV	14%	43%	18%	90%	29%	55%	0%	57%	2%	39%
CLASS V & VI	7%	17%	10%	10%	15%	5%	5%	0%	1%	1%
Irrigated Cropland SubTotal	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
FALLOW AGRICULTURAL FIELDS	1.5%	5.4%	6.1%	1.8%	3.5%	5.4%	0.0%	12.0%	29.9%	15.9%
TOTAL RANGE	66.4%	65.0%	78.5%	67.9%	53.4%	23.0%	0.0%	11.1%	17.4%	3.7%
EXCELLENT	10%		20%			10%		10%		
GOOD	60%	30%	50%	30%	50%	60%		60%	60%	10%
FAIR	15%	40%	25%	60%	30%	25%		25%	40%	70%
POOR	15%	30%	5%	10%	20%	5%		5%		20%
Range SubTotal	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	100.0%	100.0%	100.0%
FOREST	3.4%	0.4%	0.3%	0.1%	2.1%	0.1%	0.0%	0.0%	0.1%	0.0%
URBAN / OTHER	2.0%	0.1%	0.6%	0.0%	0.1%	1.1%	0.0%	0.0%	0.2%	0.0%
BOTTOMLAND	0.6%	0.7%	0.2%	0.1%	4.5%	0.2%	0.0%	0.9%	0.1%	0.5%
WATER	0.1%	0.1%	0.0%	0.0%	0.3%	0.0%	0.0%	0.1%	0.0%	0.1%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
LANDSCAPE DESCRIPTION										
FLAT (<2% SLOPE)	3%	8%	2%	14%	8%	27%	3%	7%	23%	47%
ROLLING HILLS (2-6% SLOPE)	12%	20%	8%	33%	25%	42%	58%	35%	46%	40%
STEEP HILLS (>6% SLOPE)	85%	72%	90%	53%	67%	31%	39%	58%	31%	13%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

TOTAL CROPLAND: % OF THIS SOIL IDENTIFIED AS CROPLAND . THE SUM OF LAND CAPABILITY CLASS I & II, III & IV, AND V & VI MUST ADD TO 100 %.

CLASS I & II: % OF THIS SOIL THAT IS CLASS I & II CROPLAND.

CLASS III & IV: % OF THIS SOIL THAT IS CLASS III & IV CROPLAND.

CLASS V & VI: % OF THIS SOIL THAT IS CLASS V & VI CROPLAND.

BOTTOMLAND/HARDWOODS: % OF THIS SOIL IDENTIFIED AS BOTTOMLAND/HARDWOODS BUT NOT INCLUDING FOREST OR TREES.

FOREST OR TREES: % OF THIS SOIL IDENTIFIED AS FOREST OR TREES BUT NOT INCLUDING BOTTOMLAND HARDWOODS.

GRASS LANDS: % OF THIS SOIL IDENTIFIED AS GRASS LANDS.

WATER / WETLANDS: % OF THIS SOIL IDENTIFIED AS WETLANDS.

URBAN / OTHER LANDS: % OF THIS SOIL IDENTIFIED AS OTHER LANDS INCLUDING URBAN LANDS, DEVELOPED LANDS, ABANDONED LANDS.

LANDSCAPE DESCRIPTION: % OF THIS SOIL IN EACH LANDSCAPE DESCRIPTION.

Drainage Information

CARBON SEQUESTRATION RURAL APPRAISAL

GENERAL LAND USE INFORMATION FROM LOCAL KNOWLEDGE (Drain)

STATE NEBRASKA **COUNTY** CHASE

HAS ANY PART OF THE COUNTY BEEN DRAINED (YES/NO): No
IF YES, ANSWER THE FOLLOWING.

MUID	ACRES HYDRIC SOIL IN MAP UNIT	OPEN DITCH DRAINAGE			TILE DRAINAGE		
		YEAR MAJORITY STARTED	YEAR MAJORITY ENDED	ACRES DRAINED IN MUID	YEAR MAJORITY STARTED	YEAR MAJORITY ENDED	ACRES DRAINED IN MUID
NE008	0						
NE020	0						
NE021	0						
NE033	0						
NE039	0						
NE066	0						
NE067	0						
NE068	0						
NE074	1,595						
NE110	2,656						

MUID: SOIL MAP UNIT ID FROM STATSGO. (FROM MAP)

YEAR MAJORITY STARTED AND **YEAR MAJORITY ENDED:** GIVE YEAR MAJORITY OF DRAINAGE CONSTRUCTION STARTED OR ENDED.

ACRES DRAINED IN MUID: ESTIMATE THE TOTAL ACRES OF HYDRIC SOIL DRAINED.

Irrigation Information

CARBON SEQUESTRATION RURAL APPRAISAL

GENERAL LAND USE INFORMATION FROM LOCAL KNOWLEDGE (Irrigation)

STATE NEBRASKA **COUNTY** CHASE

IS 5% OR MORE OF ANY MUID IRRIGATED (YES/NO): Yes

IF YES, ANSWER THE FOLLOWING.

	IRRIGATED ACRES IN MAP UNIT					CURRENT IRRIGATION				
MUID	BEFORE 1890	1891-1920	1921-1950	1951-1974	1975-1994	IRRIGATED ACRES IN MUID FROM GAP	ANNUAL AMOUNT APPLIED (INCHES)	PREDOMINANT SYSTEM TYPE	WATER SOURCE	AVERAGE PUMPING DEPTH FT.
NE008			160	560	685	885	13	Sprinkler < 70% Efficient	Ground	50
NE020			300	3,300	4,433	3,485	12	Sprinkler < 70% Efficient	Ground	150
NE021			150	1,600	2,330	2,032	12	Sprinkler < 70% Efficient	Ground	200
NE033				238	238	271	13	Sprinkler < 70% Efficient	Ground	125
NE039		150	1,200	5,300	5,614	5,483	13	Sprinkler < 70% Efficient	Ground	50
NE066			1,000	40,000	48,288	49,573	12	Sprinkler < 70% Efficient	Ground	150
NE067				3	3	4	11	Sprinkler < 70% Efficient	Ground	125
NE068				2,000	3,284	3,357	12	Sprinkler < 70% Efficient	Ground	200
NE074				800	4,622	5,600	11	Sprinkler < 70% Efficient	Ground	250
NE110			2,000	55,000	65,000	70,707	11	Sprinkler < 70% Efficient	Ground	125

MUID: SOIL MAP UNIT ID FROM STATSGO. (FROM MAP)

IRRIGATED ACRES IN MAP UNIT: BEFORE 1890, 1891-1920, 1921-1950, 1951-1974, 1975-1994

ENTER TOTAL ACRES IRRIGATED DURING EACH TIME FRAME.

ANNUAL AMOUNT APPLIED (INCHES): GIVE AN ESTIMATE OF THE ANNUAL AMOUNT OF IRRIGATION WATER APPLIED IN INCHES. (6, 12, 15 ETC.)

PREDOMINATE SYSTEM TYPE: ENTER MOST COMMON TYPE OF SYSTEM (Sprinkler < 70% Efficient, Surface > 60 % Efficient, Etc.)

WATER SOURCE: PULL DOWN MENU WITH SURFACE OR GROUND.

AVERAGE PUMPING DEPTH FT.: AVERAGE PUMPING DEPTH FOR GROUND WATER IN THE MUID. MUST BE WHOLE NUMBER.

Cropping And Management Information

CARBON SEQUESTRATION RURAL APPRAISAL

COUNTY LEVEL ROTATION SEQUENCE HISTORY FROM PRE 1890 TO 1950

STATE NEBRASKA COUNTY CHASE

PRE 1890 TO 1950

CROP ROTATIONS	Pre 1890			0%	PERCENT OF COUNTY FARMED IN FOLLOWING ROTATIONS			
	PRE 1890							
	CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6		PERCENT
UPLAND NON-IRRIGATED								
LOWLAND NON-IRRIGATED								
IRRIGATED								
								0%
CROP NAME								
YIELD (BU OR TONS/AC)								
CSRA CROP ACRES IN COUNTY								

Comments:

TIME FRAME: PERIOD OF TIME AS SPECIFIED.

% ESTIMATE OF COUNTY BEING FARMED DURING THIS TIME FRAME: GIVE AN ESTIMATE OF THE COUNTY AREA BEING FARMED IN THESE ROTATIONS DURING THIS TIME FRAME.

FOR INDICATED CROPS: ACTUAL CROP INFORMATION FOR UP TO SIX CROPS IN THE ROTATIONS.

CROP: CROP NAME AS SHOWN IN CROP ROTATION.

YIELD: CROP YIELD IN BU/AC FOR GRAINS OR TONS/AC FOR HAY.

Cropping And Management Information

	CARBON SEQUESTRATION RURAL APPRAISAL								
COUNTY LEVEL FARMING AND CROPPING SYSTEM HISTORY FROM 1975 TO 1994									
STATE	Nebraska				COUNT	Chase			
TIME FRAME	1975-1994								
PERCENT OF COUNTY FARMED IN FOLLOWING ROTATIONS DURIN									
CROP ROTATIONS (SPECIFY 1 TO 4)									
	CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	PERCENT		
ROTATION 1	CORN (I)						45%		
ROTATION 2	CORN (I)	DRY BEAN	WHEAT (I)	CORN SILAGE	DRY BEAN		15%		
ROTATION 3	WHEAT (D)	FALLOW					30%		
ROTATION 4	WHEAT (D)	CORN (D)	FALLOW	WHEAT (D)	MILO	FALLOW	10%		
							100%		
CROP NAME		CORN (I)	DRY BEAN	WHEAT (I)	WHEAT (D)	FALLOW	CORN (D)	MILO	CORN SILAGE
YIELD (BU OR TONS OR LBS.)									
CSRA CROP ACRES IN COUNTY									
NASS CROP ACRES IN COUNTY									
N FERT (LBS/AC)	First Date								
	First Amount								
	Second Date								
	Second Amount								
	Third Date								
	Third Amount								
	Fourth Date								
	Fourth Amount								
	Fifth Date								
	Fifth Amount								
MANURE	Season								
	Predominate Type								
AS APPLIED (TONS/AC)									
ROTATION 1									
1975-1994									
DATE	1st Operation Date								
MANAGEMENT	1st Operation								
OPERATION	2nd Operation Date								
	2nd Operation								
	3rd Operation Date								
	3rd Operation								
	4th Operation Date								
	4th Operation								
	5th Operation Date								
	5th Operation								
	6th Operation Date								
	6th Operation								
	7th Operation Date								
	7th Operation								

Annual Conservation Practice Installed

ANNUAL CONSERVATION PRACTICES INSTALLED

PRACTICES INSTALLED BY COUNTY AND SOIL MAP UNIT

USE IN REPORTING TO DOE FOR CARBON SEQUESTRATION
(USE SEPARATE SHEET FOR EACH SOIL MUID)

STATE NEBRASKA **COUNTY** CHASE **MUID** NE008
BRIDGET-MCCOOK-DUROC (NE008)

	TOTAL ACRES	TOTAL CROP LAND	CIRA 1993 GAP DATA: DRY CROP	IRRIGATED CROP	FALLOW	RANGE	FOREST	URBAN	BOTTOM LAND	WATER
MUID	5,456	**1,496**	673	740	83	3,623	188	109	33	7
COUNTY	574,144	**325,814**	100,216	178,598	46,999	241,102	1,344	1,707	2,738	1,439
PERCENT	1.0%	**0.5%**	0.7%	0.4%	0.2%	1.5%	14.0%	6.4%	1.2%	0.5%

ACRES OF CONSERVATION PRACTICES INSTALLED (ACRES)

	CURRENT CROP ROTATION (S): WHEAT (D)-CORN (D)-FALLOW		CORN (I)-DRY BEAN-WHEAT (I)		CORN (I)		WHEAT (D)-FORAGE SORGHUM-FALLOW-WHEAT (D)-FALLOW		CRP: CROPLAND CONVERT-ED TO CRP GRASS	CRP GRASS CONVERT-ED TO CROPLAND	CROPLAND CONVERT-ED TO CRP WOODLAND	CRP WOODLAND CONVERT-ED TO CROPLAND	CRP WETLANDS CREATED AND/OR RESTORED	ALL OTHER CONSERVATION PRACTICES: CROPLAND CONVERT-ED TO GRASS	GRASS CONVERT-ED TO CROPLAND	GRASS CONVERT-ED TO WOODLAND	CROPLAND CONVERT-ED TO WOODLAND	WOODLAND CONVERT-ED TO CROPLAND	WETLANDS CREATED AND/OR RESTORED	WETLANDS CONVERT-ED TO CROPLAND
	25%	PERCENT OF COUNTY IN THIS ROTATION	10%	PERCENT OF COUNTY IN THIS ROTATION	45%	PERCENT OF COUNTY IN THIS ROTATION	20%	PERCENT OF COUNTY IN THIS ROTATION												
	NO TILLAGE	MODERATE TILLAGE	NO TILLAGE	MODERATE TILLAGE	NO TILLAGE	MODERATE TILLAGE	NO TILLAGE	MODERATE TILLAGE												
1985																				
1986																				
1987																				
1988																				
1989																				
1990																				
1991																				
1992																				
1993																				
1994																				
1995																				
1996																				
1997																				
1998																				
1999																				
2000																				
CURRENT TOTAL	0	0	0	0	0	0	0	0	0.0		0.0		0.0	0.0		0.0			0.0	

ALL VALUES FOR 1985 ARE TOTAL ACRES FOR ALL ACTUAL PRACTICES APPLIED IN THE FIELD IN 1985.

ALL VALUES FOR 1986 - 2000 ARE ACRE **CHANGES** FROM THE PREVIOUS YEAR. NO TILL AND MODERATE TILL VALUES CAN BE POSITIVE OR NEGATIVE.

MUID: SOIL MAP UNIT ID FROM STATSGO. (FROM MAP)

NO-TILL: NO-TILL FARMING SYSTEM **THROUGHOUT THE ENTIRE ROTATION** WITH NO DISTURBANCE OF THE SOIL SURFACE OTHER THAN OPERATIONS FOR INJECTION OF NITROGEN AND PLANTING OF CROPS.

MODERATE-TILLAGE: MEAN ANNUAL RESIDUE COVER FOR THE ENTIRE ROTATION >= 15% AT PLANTING. IT IS THE **CROP ROTATION SYSTEM** THAT IS BEING EVALUATED, NOT A SINGLE YEAR. EXAMPLE: A WHEAT-FALLOW ROTATION THAT HAS 15% RESIDUE COVER AT WHEAT PLANTING IS MODERATE TILLAGE. A CORN-SOYBEAN ROTATION WITH 10% COVER AT CORN PLANTING AND 40% AT SOYBEAN PLANTING AVERAGES 25%, THIS IS MODERATE TILLAGE.

CRP: ALL GRASS PLANTINGS, WOODLAND PLANTINGS, AND WETLANDS CREATED UNDER CRP CONTRACT. ALSO INCLUDE CRP CONTRACT LAND THAT REVERTED BACK TO CROPLAND.

ALL OTHER CONSERVATION PRACTICES: INCLUDE ALL LAND USE CHANGE FROM CROPLAND TO DESIGNATED LAND USE, AND LAND CHANGED BACK INTO CROPLAND. INCLUDE ALL LAND USE CHANGE WHETHER NRCS WAS INVOLVED OR NOT.

GRASS CONVERSIONS: ALL GRASS PLANTING CONSERVATION PRACTICES EXCEPT CRP. (WATERWAYS, BUFFERS INCLUDING RIPARIAN BUFFERS, FILTER STRIPS, TERRACES, ETC.). USE 12' WIDTH FOR TERRACES (LF*12/43560=ACRE). USE 40' WIDTH FOR ALL OTHER PRACTICES REPORTED IN LINEAR FEET (LF*40/43560=ACRE).

TREE PLANTING: ALL CONSERVATION PRACTICES THAT INCLUDE TREE PLANTINGS EXCEPT CRP. (WINDBREAKS, SHELTERBELTS, AGRO-FORESTRY)

WETLANDS CREATED AND/OR RESTORED: ALL CONSERVATION PRACTICES THAT INCLUDE THE CREATION OR RESTORATION OF WETLANDS EXCEPT CRP.

Appendix C: County Drainage Dates

County	Early Drain	Late Drain
Adams	1944	1963
Antelope	1947	1963
Arthur	1939	1963
Banner	1940	1963
Blaine	1936	1963
Boone	1944	1963
Box Butte	1940	1963
Boyd	1942	1961
Brown	1940	1963
Buffalo	1941	1959
Burt	1947	1962
Butler	1949	1963
Cass	1945	1963
Cedar	1938	1963
Chase	1940	1963
Cherry	1938	1963
Cheyenne	1940	1963
Clay	1947	1963
Colfax	1949	1966
Cuming	1944	1968
Custer	1940	1963
Dakota	1940	1959
Dawes	1940	1963
Dawson	1938	1963
Deuel	1940	1963
Dixon	1940	1967
Dodge	1928	1961
Douglas	1935	1963
Dundy	1940	1963
Fillmore	1940	1963
Franklin	1942	1963
Frontier	1940	1963
Furnas	1943	1963
Gage	1940	1963
Garden	1943	1963
Garfield	1934	1963
Gosper	1940	1963
Grant	1938	1954
Greeley	1941	1964
Hall	1943	1963
Hamilton	1935	1951
Harlan	1942	1963
Hayes	1940	1963
Hitchcock	1940	1963
Holt	1943	1963
Hooker	1937	1963

County	Early Drain	Late Drain
Howard	1940	1964
Jefferson	1940	1962
Johnson	1943	1964
Kearney	1945	1966
Keith	1940	1963
Keya Paha	1939	1963
Kimball	1940	1963
Knox	1940	1963
Lancaster	1942	1962
Lincoln	1940	1963
Logan	1942	1963
Loup	1943	1964
Madison	1939	1963
McPherson	1949	1965
Merrick	1940	1963
Morrill	1942	1963
Nance	1938	1963
Nemaha	1943	1965
Nuckolls	1949	1963
Otoe	1943	1965
Pawnee	1942	1964
Perkins	1940	1963
Phelps	1944	1966
Pierce	1941	1965
Platte	1947	1955
Polk	1941	1961
Red Willow	1940	1963
Richardson	1942	1964
Rock	1940	1963
Saline	1949	1968
Sarpy	1940	1963
Saunders	1944	1961
ScottsBluff	1940	1963
Seward	1940	1963
Sheridan	1940	1963
Sherman	1940	1964
Sioux	1940	1963
Stanton	1942	1966
Thayer	1941	1961
Thomas	1940	1963
Thurston	1940	1962
Valley	1940	1963
Washington	1945	1961
Wayne	1935	1960
Webster	1941	1963
Wheeler	1947	1965
York	1940	1959

Appendix D: 1990-2000 Nebraska C budget spreadsheet user instructions

The following section is intended as an overview of the basic hardware and software requirements for this spreadsheet application.

System Requirements

In order to run this spreadsheet application, you will need a computer system that meets the following requirements:

- Microsoft Windows 95, 98, NT version 4.0, Windows 2000 or Windows XP
- Recommended Pentium, Pentium II, Pentium III or Pentium IV class computer
- A minimum of 2 MB of hard drive space

Please note that if your system meets the requirements as described in Appendix E. this application will function fine.

Software Requirements

The spreadsheet was written in Microsoft Excel 97 and Microsoft Excel 2000.

Installation Of The Spreadsheet

The CD contains files capable of running on machines using operating systems Windows 95, Windows 98, Windows 2000, Windows NT 4.0 or Windows XP.

- 1990-2000NebraskaCarbonBudget.xls: This is the spreadsheet that runs on Microsoft Excel, which is distributed with Microsoft Office 97 or Microsoft Office 2000

To copy the spreadsheet to your hard drive, follow these steps:

1. Insert the CD containing the spreadsheet into your CD-ROM device.
2. Open the windows explorer and click on the CD-ROM icon in the “folders” window on the left side of the screen.
3. Locate the spreadsheet and click once on the file to highlight it. Click on the “Edit” menu bar on the upper left corner of the screen, and then click on the “copy” option.
4. Locate the hard drive folder to which you wish to copy the spreadsheet. Click once on that folder to highlight it. Click on the “Edit” menu bar again, and then click on the “paste” option.

This should have copied the files to your local drive. Depending on the speed of your PC, it could take a few seconds to copy the files. In order to run the spreadsheet, first open Microsoft Excel. Select the “File” menu bar in the upper left corner, and then click on the “open” option. An “Open File” dialog box will open in the center of the screen. Find the hard drive and file folder to which you copied the spreadsheet, and select the file. Then click the “Open” button on the right side. Once the file is open, proceed to the next section for instructions how to use the spreadsheet.

Operating Instructions And Example

The spreadsheet utilizes a pull down menu located in cell B1. To activate the menu, click on cell B1 and a list of all the counties in Nebraska will appear and a list of the eight NASS regions and a state total option. The regions are identified using an additional character ‘Z’ and state totals are identified using an additional two characters ‘ZZ’. In order to extract county data from the spreadsheet, the user must specify an option from the pull down menu. Once an option is selected, four graphs will appear which provide information on:

- C changes in mineral soils from 1990-2000 for intensive, moderate and no tillage systems, grass conversions and tree/wetland conversions
- Associated acres from 1990-2000 of intensive, moderate and no tillage systems, grass conversions, tree/wetland conversions
- C changes from 1990-2000 associated with non irrigated and irrigated systems
- C changes from 1990-2000 on cultivated soils detailing the combination of non irrigated and irrigated systems and the associated intensive, moderate and no tillage cultivation system

These individual sets of data will allow land managers to compare issues across counties, regions and the state.

Installation and Use Instructions For The 'Nebraska CarbOn Management Evaluation Tool (COMET)' Database

March, 2002

A cooperative effort between the Colorado State University, Natural Resource Ecology Laboratory and USDA-Natural Resources Conservation Service

Fort Collins, CO 80523

Introduction

The following section is intended as an overview of the basic hardware and software requirements for the Nebraska COMET database. We also try to provide a basic understanding of what kind of performance you can expect from your computer when running the database. Detailed installation instructions are provided in the next section.

System Requirements

In order to run this database, you will need a computer system that meets the following requirements:

- Microsoft Windows 95, 98, NT version 4.0, Windows 2000 or Windows XP
- Pentium II, or Pentium III class computer
- A minimum of 32 MB of RAM
- A minimum of 750 MB of hard drive space

Please note that if you are using virtual memory on your hard drive (which usually uses about 120 MB of hard drive space), then you will need 750 MB of additional hard drive space above and beyond what your minimum virtual memory settings require

Screen Size Limitations

The database is optimized to run with a screen size of at least 1152 x 864 pixels. You can use the database on screens having a smaller pixel resolution, however you may need to use the scroll bars on the right side and bottom of the screen to view the data. For information on how to change your screen size, look up "To change the size of the screen area" under your Windows operating system help.

Software Requirements

The database was written in Microsoft Access 97 and compiled for either Microsoft Access 97 or Microsoft Access 2000. We've provided separate files for either version, and installation instructions are provided for either version later in this document.

If you use Access 97, we strongly recommend that you install the Office 97 service release 2b or higher. For more information on how to download/receive by mail and install this service release, see the Microsoft web site: <http://officeupdate.microsoft.com/Articles/sr2fact.htm>

If you use Access 2000, we also strongly recommend that you install Office 2000 service release 1a or higher. For more information on how to download/receive by mail and install this service release, see the following Microsoft web site: <http://officeupdate.microsoft.com/2000/downloadDetails/O2kSR1DDL.htm>

Performance Expectations

This database provides output by searching a large data table for the values that meet the county, soil type, and cropping history criteria selected by the user. This table and the queries that access these data are optimized for maximum performance. Query speed and performance limitations that you may experience will be due to limitations in processor speed, available cache memory, or RAM capacity and speed.

The database was developed on a one year-old desktop, running a Pentium III processor with 212 MB of RAM, 512K cache, operating at 1.6 GHz. It takes less than 3 seconds to open the database on this machine. It takes approximately 2 seconds to complete the very first query that is conducted in each session, and less than 2 seconds for all subsequent queries. These tests were conducted with no other software programs running. We saw substantial performance improvements when running the database on machines with faster processors. Increasing RAM memory above 128 MB did not improve performance substantially, whereas decreasing memory to below 32 MB did hamper performance very significantly. On machines that have at least 128 MB of RAM installed, users can roughly expect the query times to be inversely proportional to the speed of the processor being used. For example, a Pentium III class machine with 128 MB of RAM and a processor running at 733 MHz will access and display the data in about ½ of the time required by the Pentium II at 400 MHz. In a similar vein, running the database on machines with Celeron Processors can result in decreased performance, since the Celeron lacks cache memory and has less processing power. We wish to advise users that running the database on older Pentium-class machines can be frustrating.

Some Tips On Running Microsoft Access

This database program was written and compiled using standard dynamic link libraries provided by Microsoft with Access 97, 2000, and the Visual Studio Development Environment. There are no user-defined or custom libraries used. It will not overwrite any system or locally defined libraries.

We have found, particularly with Office 97, that running applications in a multitasking environment can impede performance of this database. If you wish to maximize the performance of this database, we recommend you close most or all other concurrently running programs.

We have also found that Microsoft Access 97 and Access 2000 can be somewhat “buggy” when you run them in a multitasking environment. This is particularly true when running them with Netscape Communicator and/or Microsoft Internet Explorer open. Users may experience infrequent or seemingly random program crashes, during which Access abruptly warns the user of an operating system error and then closes the program. If you experience this only occasionally, we believe you should try to live with the system crashes. If this happens repeatedly or under circumstances that you can repeat, then you should consider seeking assistance from your system administrator or from Microsoft.

Installation Of The Database

The two CD's contain files capable of running on machines using operating systems Windows 95, Windows 98, Windows 2000, Windows NT 4.0 and Windows XP. One contains the 'Nebraska_COMET_97.mde' database, the 'user_instructions.ppt' presentation, 'Installation_and_Use.doc' document, the '1990-2000NebraskaCarbonBudget.xls' spreadsheets and the 'Nebraska_Final_Report.pdf'. The other contains the 'Nebraska_COMET_2000.mde' database, the 'user_instructions.ppt' presentation, 'Installation_and_Use.doc' document, the '1990-2000NebraskaCarbonBudget.xls' spreadsheets and the 'Nebraska_Final_Report.pdf'.

- Nebraska_COMET_97.mde: This is the database version that runs on Microsoft Access, version 7.0 (also called Access 97), which is distributed with Microsoft Office 97
- Nebraska_COMET_2000.mde: This version runs with Microsoft Access 2000, which is distributed with Microsoft Office 2000
- user_instructions.ppt: This file is a Microsoft PowerPoint presentation which provides step by step procedures necessary to use the COMET database
- Installation_and_Use.doc: This is a Microsoft Word document which provides the step-by-step procedures for use of the COMET database
- 1990-2000NebraskaCarbonBudget.xls: This file summaries the C sequestration results by county, by region and for the entire state
- Nebraska_Final_Report.pdf: This file is a Adobe Acrobat file that can be read using Adobe Acrobat Reader and is the final report to the Nebraska Conservation Partnership.

IMPORTANT NOTE!
THE DATABASE WILL NOT RUN DIRECTLY OFF OF THE CD.
TO RUN THE DATABASE, YOU MUST COPY THE FILE FROM THE CD TO YOUR HARD DRIVE.

In order to run the database, you **must** copy the database version that you wish to use off of the CD and onto your hard drive. This is necessary because Microsoft Access will try to make changes to the file each time you open the database. If it cannot do so (which will be the case on a CD-ROM, since it is a read-only device), it will report an error and fail to open the database.

To copy the database to your hard drive, follow these steps:

1. First create a new folder titled “comet” on your C:\ drive using windows explorer.
2. Insert the CD containing the database into your CD-ROM device.
3. Open the windows explorer and click on the CD-ROM icon in the “folders” window on the left side of the screen.
4. Locate the database (97 or 2000) you wish to copy. Click once on the file to highlight it. Click on the “Edit” menu bar on the upper left corner of the screen, and then click on the “copy” option.
5. Locate the new ‘comet’ folder on the c:\ drive (created in 1 above). Click once on that folder to highlight it. Click on the “Edit” menu bar again, and then click on the “paste” option.
5. Repeat steps 3-5 above to copy the ‘user_instructions.ppt’ and the ‘Installation_and_Use.doc’ files to the c:\comet\ directory on your hard drive. (Note: This has to be done so the tutorial and installation instructions will function properly).
6. Repeat steps 3-5 above to copy the (1990-1999NebraskaCarbonBudget.xls) spreadsheets and the (Nebraska_Final_Report.pdf) final report to your hard drive.

This should have copied the files to your local drive. Depending on the speed of your PC, it could take from a few seconds to several minutes to copy the files. In order to run the database, first open Microsoft Access. Select the “File” menu bar in the upper left corner, and then click on the “open” option. An “Open File” dialog box will open in the center of the screen. Find the c:\comet\ directory and select the database file. Then click the “Open” button on the right side. The database file will probably take from 5-20 seconds to open, depending on the performance of your machine.

The tutorial ‘user_instructions.ppt' can be viewed directly from the database by clicking the 'Tutorial' button on the main screen. The tutorial should be reviewed prior to using the database.

Operating Instructions And Example

In order to extract data from the database, the user must specify the following input parameters:

- County
- Base history
- Recent history
- Soil surface texture (e.g. SICL = silty clay loam, SL = sandy loam, etc.)
- Soil hydric condition (yes or no)

- Management System A
- Management System B

The first three items are fairly self-explanatory. The user specifies the management system by defining crop rotation and tillage method for twenty-year increments (1974-1994, 1995-2014) in two scenarios. By specifying two scenarios, the operator is able to compare carbon sequestration potential in two different management regimes. The power point presentation 'user instructions.ppt' provides a step by step procedure on how to use the database.

The following procedure explains the various parts of the database.

The user first specifies the county of interest in the **County** field.

Use the mouse to click on the **Base** field and select one that closely matches the landscape position and irrigated option prior to 1950.

Use the mouse to click on the **Recent** field and select one that closely matches the crop rotation and irrigation option for the 1950-1974 time period.

Use the mouse to click on the downward-pointing arrow in the **Surface Texture** box. This presents a list of the most common surface textures found in the county selected, based on information in the STATSGO database. Note that the database will not allow a user to specify a soil texture until a county is specified. The codes refer to the following surface textures:

- CL (clay loam)
- L (loam)
- LS (loamy sand)
- S (sand)
- SIC (silty clay)
- SICL (silty clay loam)
- SIL (silt loam)
- SL (sandy loam)

The user then specifies whether the soil is hydric or not (Yes or No) in the **hydric?** field. Note that we have specified hydric condition according to information in the STATSGO database.

Use the mouse to click on the downward-pointing arrow in the **Irrig** field under Management System A. This presents a D (non-irrigated) or I (irrigated) options and the user must select one.

Use the mouse to click on the downward-pointing arrow in the **Crop,75-94:** field under Management System A. This presents the crop rotation options and the user must select one.

Use the mouse to click on the downward-pointing arrow in the **Tillage,75-94:** field under Management System A. This presents the tillage options and the user must select one. The codes correspond to the following:

- current practice – tillage as reported on the CSRA
- intensive tillage - multiple tillage operations every year
- moderate tillage - spring disk, harrow and planting, also included every other year tillage as in corn-bean rotation where the beans are planted into the corn residue and strip tillage
- no tillage – no tillage operations except to inject N and to plant

Use the mouse to click on the downward-pointing arrow in the second **Irrig** field under Management System A. This presents a D (non-irrigated) or I (irrigated) options and the user must select one.

Use the mouse to click on the downward-pointing arrow in the **Crop,95-14:** field under Management System A. This presents the crop rotation options and the user must select one.

Use the mouse to click on the downward-pointing arrow in the **Tillage,95-14:** field under Management System A. This presents the tillage options and the user must select one.

Note that the method available in the database is limited in some cases. For example, all rotations that have CRP included are limited to non-irrigated crop rotations. Also note that the options for the **Crop,95-14:** option are offered in 20 year blocks only, with CRP offered as a separate block and can be different than the **Crop,74-94:** option.

Repeat steps for **Management System B**.

When these data are entered into the fields as described above, the **Show Data** button will become active. Clicking on that button will execute a query that extracts the data requested from the database. It will then show the data in graphic format (one graph for each scenario). The differences between the two scenarios are shown in tabular format.

Clicking on the **View Data Table** button brings up the database table that contains the data from the model runs. You can copy and paste data as needed from this table. Clicking on the **Reset** button clears the data input fields and sends the cursor back to the **County** field to start over.

Interpreting The Graphs

Note that the graphs have two data lines. Units are specified in metric tonnes/hectare (1 hectare = 2.47 acres). The green line shows the carbon levels in the soil + residue category under the management scenario specified. The blue line shows soil carbon levels without residues included.

Change Read-Only Attributes Of Files After Copying To Your Hard Drive

When installing the database and tutorial program from CD to your hard drive, users will need to change the attributes of the files so that they are no longer read-only. Files that are written to CD's are typically made read-only, and the file remains Read-Only when it is copied back to a hard drive. Following are instructions on how to change the read-only attributes of the files copied to your hard drive, so the database and tutorial will run:

- With "Windows Explorer" or the "My Computer" folder open, and after copying the files from the CD to the hard drive, click once on the Nebraska_COMET_2000.mde so that it is highlighted
- With the file highlighted, click once on the "File" menu, and then click once on the "properties" option. In the window that opens, select the "General" tab and un-check the "Read-Only" box near the bottom of the window. You can un-check the box by clicking on it once
- Click once on the "Accept" button to finalize the change, and then click once on the "OK" button to close the window
- Repeat step above for the other files on the CD

Tutorial Sometimes Fails To Load

We have found that on some machines, the tutorial fails to load completely after clicking on the "Tutorial" button on the upper right corner of the screen. The software is written to open the 'user_instructions.ppt' file automatically and load the tutorial presentation. We acknowledge that this is a bug in the software and we are preparing a solution for future distributions of the database. If this problem occurs on your computer, use the following simple workaround to allow you to view the tutorial:

- With PowerPoint open, click once on the "File" menu. Then click once on the "Open" option
- In the "Open" window that appears on the screen, locate the file 'user_instructions.ppt' on your hard drive. Click once on the file to highlight it and then click once on the "Open" button in the lower right corner of the window
- After viewing the tutorial, close PowerPoint by selecting the "Exit" option from the "File" menu. The operating system should return directly to the database

Troubleshooting

User errors generally arise from not understanding the assumptions and limitations placed upon the model used to generate the data. We have found in the initial testing that many users tried to specify rotations or soil types that did not exist in the database. Keep in mind that we limited the number of soil types and crop rotations used in the model to those most commonly found. Those not found in the list were left out of the model run for reasons of simplicity and manageability.

We wish to know about software bugs that arise, and to receive feedback from users about rotations, tillage practices, and soil textures that we should consider modeling for the database. Please report these items by e-mail to:

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(970) 491-7662 VOICE
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In your feedback, it is necessary that you provide the following information:

- Operating system (Win95, Win98, Win2000, NT4.0 XP)
- Version of Access (7.0/97, 2000, 2001 or XP)
- A complete description of the bug including examples
- Please avoid using jargon
- The circumstances that lead to the bug or error condition
- An exact description of the error code and text that appears

Appendix F: Public Outreach

General Public Distribution

National

- Nebraska Carbon Storage Project Going Strong. National Association of Conservation District news & views, July/August 2000
- Global Climate Change Emerging Issue of a New Century – National Association of Conservation District publication
- USDA Global Change Fact Sheet Soil Carbon Sequestration: Frequently Asked Questions, December 2000

Regional

- Utilities hope 'less till' plan will reduce global warming – The Nebraskapolis Star – Business / March 22, 2000
- Agriculture and environment: growing carbon for climate change – ECOS The environmental communiqué of the states, A publication of The Council of State Governments, Vol. 7, No 4

State

- IASCD Report Card March 2000
- Conservation Practices May Help Meet Climate Control Challenge – Marion County SWCD March 2000 Newsletter
- Farmers may hit pay dirt by growing cleaner air – The Daily Ledger April 19, 2000
- Carbon credit trading helps mitigate carbon dioxide effects – The Dearborn County Register June 1, 2000
- Cutting Edge Scientific Research Conducted Locally – NRCS media release March, 2000
- Carbon Sequestration Could Lead to Benefits for Conservation & Agriculture – Nonpoint Notes, April, 2000
- Possible Solutions for Greenhouse Effect – Harrison County SWCD Newsletter, September, 2000
- Growing Carbon for Climate Change – State Trends, Fall 2000 V.6, I.4
- Carbon sequestration benefits air, soil and water quality – Indiana Agrinews, January 26, 2001
- Carbon Storage – Henry County SWCD Newsletter, April, 2000

- Carbon Storage – A New Crop – Floyd County SWCD Newsletter, April 2000
- Local farmers may soon be producing an unknown crop – Hendricks County Flyer, April 6, 2000

Meeting/Conference Presentation

Year	Meeting/Conference	Location	Audience
1999	NRCS State Partnership Meeting	Lincoln, NE	State
2000	Nebraska Association of NRD's Annual Meeting	Lincoln, NE	State
2001	Indiana Association of Conservation Districts Annual Conference	Indianapolis, IN	State
2001	NRCS State Partnership Meeting	Indianapolis, IN	State
2001	NRCS State Partnership Meeting	Fresno, CA	State
2001	CO Association of Conservation Districts	Fort Collins, CO	State
2001	National Wheat Growers Association Annual Meeting	New Orleans, LA	National
2001	USDA Ag Outlook Forum	Washington, DC	National
2001	Soil & Water Conservation Society International Meeting	Myrtle Beach, SC	International
2001	9th U.S.-Japan Workshop on Global Climate Change	Tokyo, Japan	International
2001	EU workshop on Carbon Sequestration in European Grasslands	Foulum, Denmark	International
2002	USDA Ag Outlook Forum	Washington, DC	National